THE STRUCTURE OF SOME LEAVES AND FRUCTIFICATIONS OF THE GLOSSOPTERIS FLORA OF TANGANYIKA

D. D. PANT

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THE STRUCTURE OF SOME LEAVES AND FRUCTIFICATIONS OF THE GLOSSOPTERIS FLORA OF TANGANYIKA

BY

DIVYA DARSHAN PANT

(Botany Department, The University, Allahabad, India)

Pp. 125–175 ; *Plates* 18–21 ; 21 *Text-figures*

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THE STRUCTURE OF SOME LEAVES AND FRUCTIFICATIONS OF THE GLOSSOPTERIS FLORA OF TANGANYIKA

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CONTENTS

SYNOPSIS

The epidermal and cuticular structure of three new species of *Glossopteris*, a species of *Rhabdotaenia* gen. nov. (*Taeniopteris* in part), some scale leaves, microsporangia and two new species of seeds (*Spermatites* Miner) from the Mhukuru Coalfield, Tanganyika are described. *Taeniopteris danaeoides* Royle from India is referred to *Rhabdotaenia* on the basis of its epidermal structure. Two discs bearing microsporangia, from Newcastle, New South Wales, are described and their sporangia compared with those from Africa.

I. INTRODUCTION

The study of the cuticular structure of fossil plant compressions has rapidly advanced but comparatively little work has yet been published on the structure of plants of the *Glossopteris* flora. The cuticular structure of *Glossopteris* itself, the most widespread genus of the flora, is but briefly described for only two leaves, *G. indica* Schimper (Zeiller, 1896 : 369, fig. 13) and *G. angustifolia* Bgt. (Sahni, 1923 : 277,

pl. 17, figs. 2, 3). These cuticles are, however, so dissimilar that they have always pointed to the need for more extensive work on the subject and the present paper is an attempt in this direction.

The material described here was obtained from six borehole cores from the Mhukuru Coalfield in Tanganyika. The cores have been described by Harkin (1953) and in the same paper Professor J. Walton (Appendix IV : 28) gave a preliminary report on their flora, a typical *Glossopteris* assemblage. Professor Walton later handed the cores to me for detailed study. The work was begun in his laboratory in Glasgow and completed at Professor Harris's laboratory in Reading.

The cores are only about 5 cm. in diameter, hence the specimens are small, but the matrix is fine and is entirely unoxidized and the plants are beautifully preserved compressions. An unexplained feature of the preservation is that while some leaves are complete, as is ordinarily the case, others show only one epidermis with more or less of the mesophyll adherent to it ; the veins may be present or they may be missing and merely represented by the epidermal cells. It looks as though the leaf had split through the middle before preservation and the two halves were preserved separately. As a result the single epidermis is thin enough to be transparent and it shows its cell outlines very clearly, often far more clearly than can be seen in the cuticle. It is easily removed from the rock by celloidin pulls. It also shows the lignine thickenings of the guard cells which are destroyed when the cuticle is prepared.

The smaller fossils (scale leaves, microsporangia and seeds) described in this paper owe their interest to the excellent preservation of their cuticles. One of the small *Vertebraria* axes which show their tracheids and ray tissue has already been described (Pant, 1956).

The other fossils occurring in the cores consist of a single fragment of a leaf sheath of *Schizoneura*, some equisetaceous stems, a few megaspores, abundant two-winged pollen grains, a few three-winged, one-winged and unwinged examples and numerous slender roots showing scalariform metaxylem and spiral and annular protoxylem with or without a surrounding sheath of fibres. These are not described here. Walton (1953 : 30) had, in addition, recorded the occurrence of two specimens of *Noeggerathiopsis* in these cores (a third is a counterpart) but after examining the specimens and preparing their cuticles I think that they are poorly preserved midrib regions of *Glossopteris* leaves.

According to Harkin (1953 : 9) the plant-bearing shales at Mhukuru belong to the " Upper Coal Measures " and to the " upper part of K_3 bed " regarded as corresponding to the upper part of the Ecca Series in South Africa (see Harkin, 1953 : 7, Table 2). Walton (1953 : 28) also regards the age as Ecca. His determinations were, however, based on a preliminary identification of the fossils which are here regarded as new species and therefore do not indicate a precise age.

Genus ***GLOSSOPTERIS*** Brongniart

The epidermis of the various species described here is of a single general type and it may well be that all these species belong to one true genus. *Glossopteris indica*

FIG. 1. A–E, *Glossopteris fibrosa* n. sp.; F, *G. hispida* n. sp. A, details of venation of a typical leaf showing fibres in certain meshes. V.34444. × 10. B, leaf apex with short meshes. V.34444. × 2. C, leaf apex with long meshes; a few anastomoses may have been missed. V.34446. × 2. D, leaf base showing narrow meshes near the margin. The midrib shows lumps but no bundles. V.34447. × 2. E, two leaf fragments, on the left, middle region, on the right, near base; some anastomoses may have been missed. Holotype, V.34440*a*. × 2. F, middle region of leaf showing veins, midrib and part of the margin. Holotype, V.34450*a*. × 2.

of Zeiller (1896) however, appears from the figure to be different in cuticle and may belong to another genus ; (I was unable to find Zeiller's original slide in Paris). The fructifications described by Zeiller (1902) as *Ottokaria*, and by Plumstead (1952, 1956) as *Scutum* and *Lanceolatus* also suggest generic differences but at present I consider it premature to make new genera out of *Glossopteris*.

Glossopteris fibrosa n. sp.

(Pl. 18, figs. 1–5 ; Pl. 19, fig. 1 ; Text-figs. 1, A–E ; 2, 3)

DIAGNOSIS. Leaf long lanceolate, average length estimated at between 13 and 30 cm.; width in middle region 4–6 cm. Basal part tapering very gradually, margins becoming almost parallel to midrib at base, two sides of lamina often of unequal width. Apex more or less obtuse. Petiole not known. Midrib up to 0·5 cm. wide below, persisting to apex but becoming narrow, probably depressed above and convex below. Midrib sometimes showing small lumps. Margins normally entire or slightly undulate, rarely lobed, slightly curved downwards and thickened. Veins arising from midrib at a very acute angle in all parts of the leaf but soon bending outwards for about 1 cm. and then continuing at an angle of 60°–80° to the midrib except in basal and apical parts where veins less arched making angles of 40°–50° only with midrib. Veins crossing lamina at a concentration of about 20–30 per cm. near midrib and 32–44 per cm. near margin (measured at right angles to majority of veins). Veins anastomosing in all parts of lamina but more frequently near midrib. Average width of meshes 0·5 mm. (ranging from 0·4 to 0·9 mm.) near midrib and 0·3 mm. near margin. Meshes in middle of lamina of varied length, average length 7 mm.; extreme base of leaf with lamina only one or two short meshes wide. Veins bending forwards at margin. Veins normally 90–160 μ thick (some up to 250μ), prominent on underside.

Substance of lamina rather thin, meshes showing elongated fibres running parallel with main veins, about 5–14 μ wide, fibres occasionally crossing connecting veins or moving to join main veins ; also showing palisade-like cells 15–30 μ wide and spongy mesophyll cells elongated transversely to the veins averaging 60 μ long and 20 μ wide.

Upper epidermis of lamina usually without stomata. Cells between veins averaging 86 μ long and 44 μ wide tending to form rows parallel with veins. Lateral (anticlinal) walls about 3 μ thick, arched or nearly straight, never sinuous. Surface wall either without any papilla but appearing finely mottled or occasionally with several small papillae with or without an obscure larger median papilla. Sometimes numerous small papillae tend to be in longitudinal rows or are replaced by longitudinal striations. Cells over veins and often above fibres somewhat narrower and longer. In basal part of leaf and near margin upper epidermal cells become isodiametric but elongated along the margin itself. Cells over midrib with thicker walls (about 6 μ thick), elongated or short, rectangular or polygonal, tending to occur in longitudinal rows, stomata present but rare. Midrib cells often with a moderately conspicuous papilla. Trichomes absent.

Upper cuticle of lamina rather thick (up to 3 μ thick). Cell outlines thin, straight,

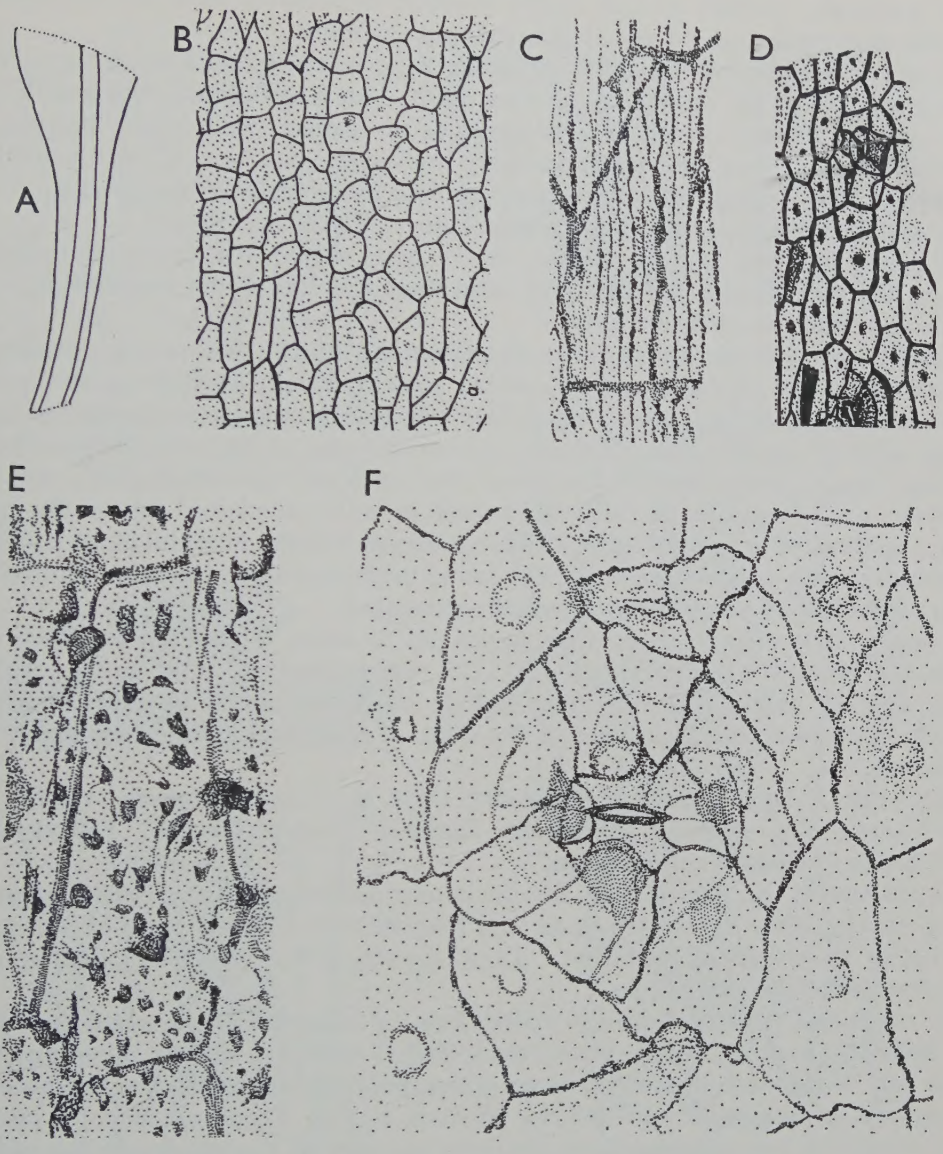

FIG. 2. *Glossopteris fibrosa* n. sp. A, leaf base showing slight asymmetry at the top, venation mentioned on p. 130. V.34445. × 1. B, upper cuticle of lamina showing cells arranged in longitudinal rows parallel with the veins. V.34448. × 125. C, cell of upper epidermis over vein showing longitudinal striations with small papillae arranged along them at some places. V.34449*a*. × 800. D, epidermis (? upper) of midrib showing stomata and thick-walled cells with median papillae. V.34444*a*. × 125. E, a cell of upper epidermis showing papillae of various sizes. V.34449*a*. × 800. F, lower cuticle showing stoma with outlines of guard cells distinctly marked at the poles but less distinct at the sides (see also Pl. 18, fig. 4). V.34443. × 800.

not bordered; surface of cells finely mottled, sometimes with obscure median papilla or several small papillae; otherwise as epidermis.

Lower epidermis of lamina showing isodiametric polygonal cells or cells somewhat elongated in various directions between veins, but longitudinally elongated cells over veins. Average width of cells about 44 μ. Lateral walls nearly straight or curved, never sinuous, sometimes unevenly thickened. Surface wall finely mottled, often showing a single ill-defined more or less prominent median papilla. Cells over midrib as on upper side but stomata absent. Trichomes absent.

Stomata frequent in vein meshes, rarely over veins; concentration typically about 125 per sq. mm. Orientation inconstant, tending to be longitudinal near veins and transverse between them.

Stomata haplocheilic, partly or completely amphicyclic but sometimes monocyclic. Guard cells about 45 μ long and 25 μ wide; sunken, usually aperture alone exposed in a small pit about 30 μ deep. Subsidiary cells 4–8, forming a very irregular ring; often slightly smaller than ordinary epidermal cells, polar cells unspecialized; surface usually somewhat thicker than that of other epidermal cells; usually showing a rather prominent thickened papilla or with a thickened rim on the inner side, papilla more or less hollow. Papillae pointing over the stomatal pit or pointing outwards; often a second faint papilla occurs in the middle of the cell. Encircling cells unspecialized, sometimes tangentially elongated.

Lower cuticle rather thinner than upper (up to about 2 μ thick), anticlinal cell walls thin without uneven thickenings. Cell surface finely mottled, usually with a faint median papilla. Guard cells slightly thickened round aperture, outlines clearly marked at poles, less clear at the sides. Lower cuticle otherwise like lower epidermis.

HOLOTYPE. Brit. Mus. (N.H.) Palaeont. Dept. no. V.34440 (Text-fig. 1, E).

LOCALITY AND HORIZON. Mhukuru Coalfield, Songea District, Tanganyika; Ecca Series (" Upper Coal Measures ").

DESCRIPTION. *G. fibrosa* is by far the commonest of all *Glossopteris* remains in the borehole cores. There are in all 146 fragments of different parts of its leaves (including 16 apices and 15 bases). The diameter of the cores being about 5 cm. no complete leaves can be seen.

In about half the specimens the midrib forms a fairly deep groove and the veins are distinctly sunken. In the others the midrib is only very slightly raised and the veins flat. I regard the first set as leaves preserved with the lower surface downwards, the second set, preserved upside down (Walton, 1936). I conclude that the midrib and veins were very prominent on the lower side but on the upper side the midrib was slightly sunken and the veins flat. The margin also is slightly curved downwards.

The veins and midrib contain abundant scalariform tracheids from 14–26 μ wide. Tracheids with uniseriate or multiseriate bordered pits also occur in the midrib; some pits show crossed apertures (see Text-figs. 3, B, C).

In epidermal pulls, the guard cells of the more exposed stomata show lateral and polar lignine lamellae of Gymnosperm type but these dissolve on maceration.

There is great variety in the surface of the upper epidermal cells of specimens referred to *G. fibrosa*. A very common state is a finely mottled wall but other speci-

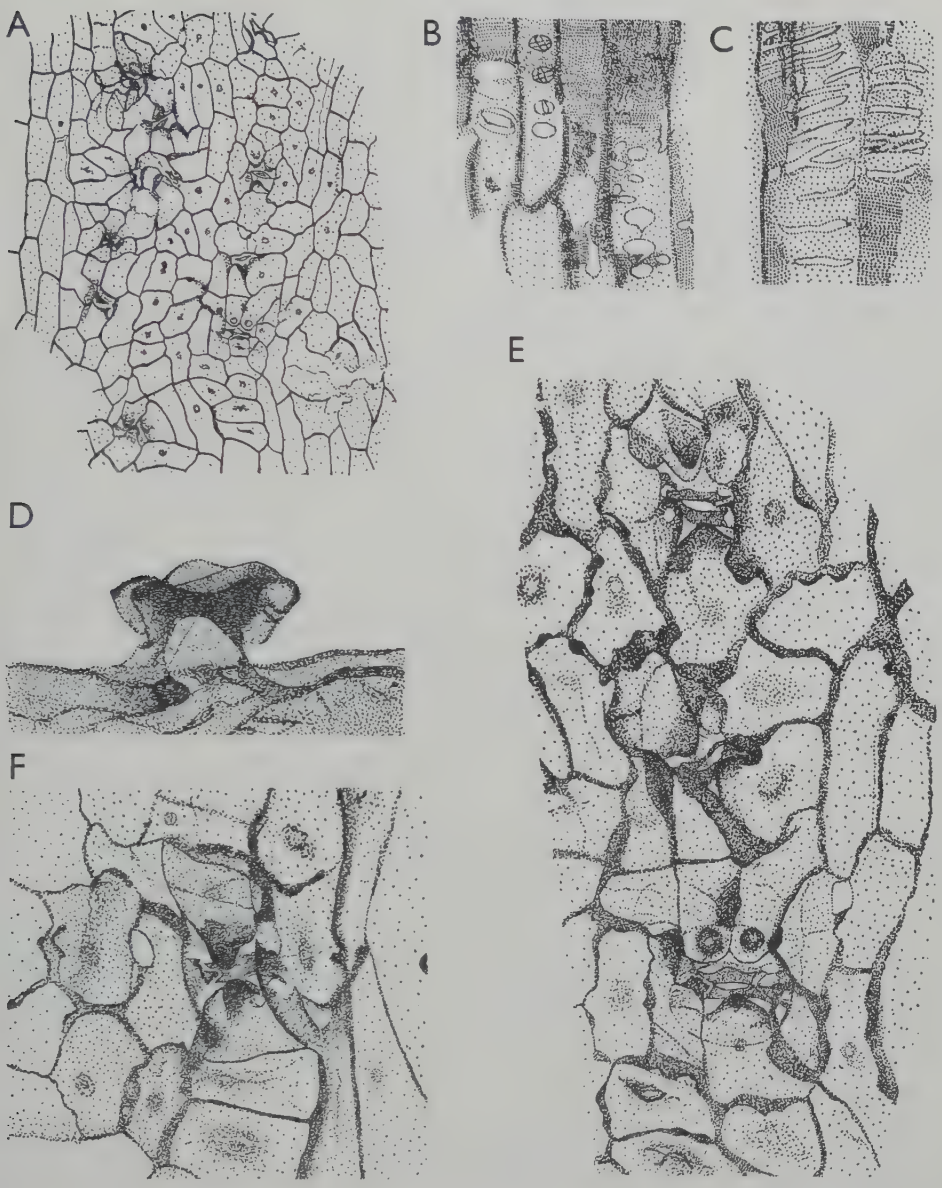

FIG. 3. *Glossopteris fibrosa* n. sp. A, lower epidermis showing a stomatal area between two veins. V.3444*od*. × 125. B, tracheids of midrib showing bordered pits ; some of them show crossed apertures. V.3444*od*. × 400. C, scalariform tracheids from a vein. V.3444*od*. × 800. D, stoma at a fold of the lower epidermis, seen from inner side (see also Pl. 18, fig. 2). V. 3444*1*. × 400. E, part of A, more magnified, showing more and less exposed stomata. × 400. F, a stoma with four subsidiary cells and lateral and polar lignine lamellae in guard cells. V.3444*od*. × 400.

mens show a faint papilla and others several moderately developed small papillae, a state which grades into mottling and also grades into longitudinal striations. One leaf showed striations in cells over a vein and close to them cells with several small papillae and one faint larger papilla. In some leaves the lower cuticle is thin and looks much like that of *G. hispida* (details are however obscure), but differs in the absence of hair bases.

The only additional characters to be noted are those seen in exceptional specimens and which may be the result of peculiar preservation. The upper epidermis of a leaf shows pale cell walls and dark cell contents, the cells being full of granules of various sizes (Pl. 18, fig. 3).

It was noted that two-winged pollen grains, more commonly varying in size from 40–60 μ across, occur abundantly on both sides of the leaves.

Comparison. *G. fibrosa* looks much like many of the figures given by various authors (e.g. Brongniart, 1828 ; Dana, 1849 ; Feistmantel, 1878–79, 1879, 1880–81, 1882, 1886 ; Zeiller, 1896, 1902 ; Arber, 1905*a* ; Walkom, 1922, 1928 ; Walton, 1929 ; Plumstead, 1952, 1956) under the names *G. browniana* var. *indica* (*G. indica*), *G. angustifolia*, *G. browniana* var. *australasica* (*G. browniana*) and *G. communis*. I have seen the holotypes of the first two species and a syntype of *G. browniana* var. *australasica* Brong. (No. 507) in the Natural History Museum in Paris. All are clearly different because they lack fibres in vein meshes. None of these has satisfactorily preserved cuticle but there is a little information about *G. browniana* (see Table I). I have examined much other material attributed to these species in the British Museum (Nat. Hist.), École de Mines, Paris and in Oxford University Museum ; the only specimens which appear to have fibres are those described by Bunbury (1861) as *G. browniana* var. *indica* (V.19617) and by Walton (1929, pl. c, fig. 19) as *G. indica* (V.20778) both in the British Museum (Nat. Hist.). Two slides showing fragments of *Glossopteris* leaves from Richmond Vale, Australia, sent to the British Museum by Dr. A. B. Walkom, show similar fibres and venation. A cuticle was prepared but cell outlines are very obscure. The only other *Glossopteris* with similar fibres is *G. hispida* described in this paper (see p. 140 for comparison).

Glossopteris cuticles have been described from specimens identified as *G. indica* by Zeiller (1896) and *G. angustifolia* by Sahni (1923). I assume that these determinations are correct. *G. fibrosa* differs clearly in cuticle from both (see Table I). I have examined a few other cuticles of *Glossopteris* leaves with this kind of venation and all are different.

Glossopteris hispida n. sp.

(Pl. 18, figs. 6, 7 ; Pl. 19, fig. 3 ; Pl. 20, figs. 1, 2, 7 ; Text-figs. 1, F ; 4–6)

Diagnosis. Leaf 4·3–7 cm wide, elongated, length unknown. Midrib up to at least 0·5 cm. wide, showing numerous longitudinal strands anastomosing at long intervals. Lateral veins departing from midrib at an acute angle (10°–20°) but soon arching outwards and continuing at an angle of 60°–80° to midrib ; concentration of veins 19–26 per cm. near midrib, 28–35 near margin (measured transversely to the majority of veins) ; meshes shorter near midrib, longer towards margin but

TABLE I.—*Comparison of Certain* Glossopteris *Leaves with Narrow Vein Meshes and the Present New Species*

Material	Fibres between veins	Thickness of cell walls	Upper epidermis or cuticle	Lower epidermis or cuticle
1. With type *G. browniana* var. *australasica* Bgt. Mus. Hist. Nat. Paris, no. 507. *Loc.* Hawkesbury River, nr. Port Jackson, N.S.W.	Absent	Thin	Lateral walls straight, surface with several small papillae	Lateral walls sinuous, ordinary cells sometimes with median papillae, subsidiary cells with papillae overhanging stomatal pit. Trichome bases absent.
2. ? With type *G. browniana* var. *australasica* Bgt. Oxford Univ. Mus., no. FW5. *Loc.* " New Holland ". (The type cannot be traced)	,,	,,	Ditto	Lateral walls sinuous, ordinary cells sometimes with median papillae, subsidiary cells ?, trichome bases absent.
3. *Glossopteris* sp. No. V.19164. *Loc.* Burdwan, Bengal, India	,,	,,	Lateral walls straight to wavy, surface with striations or several small papillae (never single)	Lateral walls slightly wavy or almost straight, ordinary cells without median papillae, subsidiary cells with papillae overhanging stomatal pit. Trichome bases absent.
4. *G. angustifolia* (Sahni, 1923). *Loc.* Raniganj, Bengal, India	No data	,,	Lateral walls wavy, surface with "numerous extremely fine punctuations closely arranged along wavy parallel lines "	Lateral walls almost straight, ordinary cells without papillae, some subsidiary cells with median papillae. Trichomes? (probably absent).
5. *Glossopteris* sp. Oxford Univ. Mus., no. FW8. *Loc.* Newcastle, N.S.W.	Absent	,,	Lateral walls straight, surface with single median papilla	Lateral walls slightly wavy, ordinary cells with median papillae, subsidiary cells with papillae overhanging stomatal pit. Trichomes absent.
6. *Glossopteris* sp. No. V.34492. *Loc.* Richmond Vale, N.S.W.	Present	,,	Details and cell outlines very obscure in cuticle	Details and cell outlines very obscure in cuticle.

Table I.—*continued*

Material	Fibres between veins	Thickness of cell walls	Upper epidermis or cuticle	Lower epidermis or cuticle
7. *Glossopteris* sp. A. No. V.34467. *Loc.* Mhukuru Coalfield, Tanganyika (2 specimens)	Absent	Thin	Lateral walls straight or arched, never wavy, bordered, surface with a median papilla or mottled	Lateral walls almost straight, ordinary cells usually with single median papillae, subsidiary cells with papillae overhanging stomatal pit. Trichomes absent.
8. *G. fibrosa* . . . *Loc.* Mhukuru Coalfield, Tanganyika (many specimens)	Present	,,	Lateral walls straight or arched, never wavy, not bordered, surface mottled or with single median papilla or numerous papillae or with longitudinal striations	Ditto
9. *G. hispida* . . . *Loc.* Mhukuru Coalfield, Tanganyika (4 specimens and some small fragments)	,,	,,	Lateral walls straight, never wavy, surface with numerous papillae or mottled	Lateral walls straight to sinuous, ordinary cells without median papillae, subsidiary cells with papillae overhanging stomatal pit. Trichomes and trichome bases present.
10. *G. indica* (Zeiller, 1896). *Loc.* Frances, Johannesburg, S. Africa	No data	Thick	No data	Lateral walls straight, ordinary cells and subsidiary cells without papillae. Trichomes ?
11. *G. colpodes* . . *Loc.* Mhukuru Coalfield, Tanganyika (many specimens)	Absent	Thin	Lateral walls usually wavy, straight near midrib and margins and over midrib and veins, surface of most cells with a median papilla	Lateral walls markedly wavy but straight near midrib and margins and over midrib and veins, surface often with a median papilla. Trichomes absent.

often the ultimate mesh is again short. Meshes average about 0·8 mm. wide (ranging from about 0·6–1 mm.) near midrib and about 0·3 mm. wide near margin, average length of meshes about 4 mm. Veins and midrib prominent on the lower side, midrib also slightly depressed on the upper. Veins up to 140 μ thick. Margin entire, slightly thickened and slightly curved downwards, occasionally lobed.

Substance of lamina thin, showing spongy mesophyll cells elongated transversely

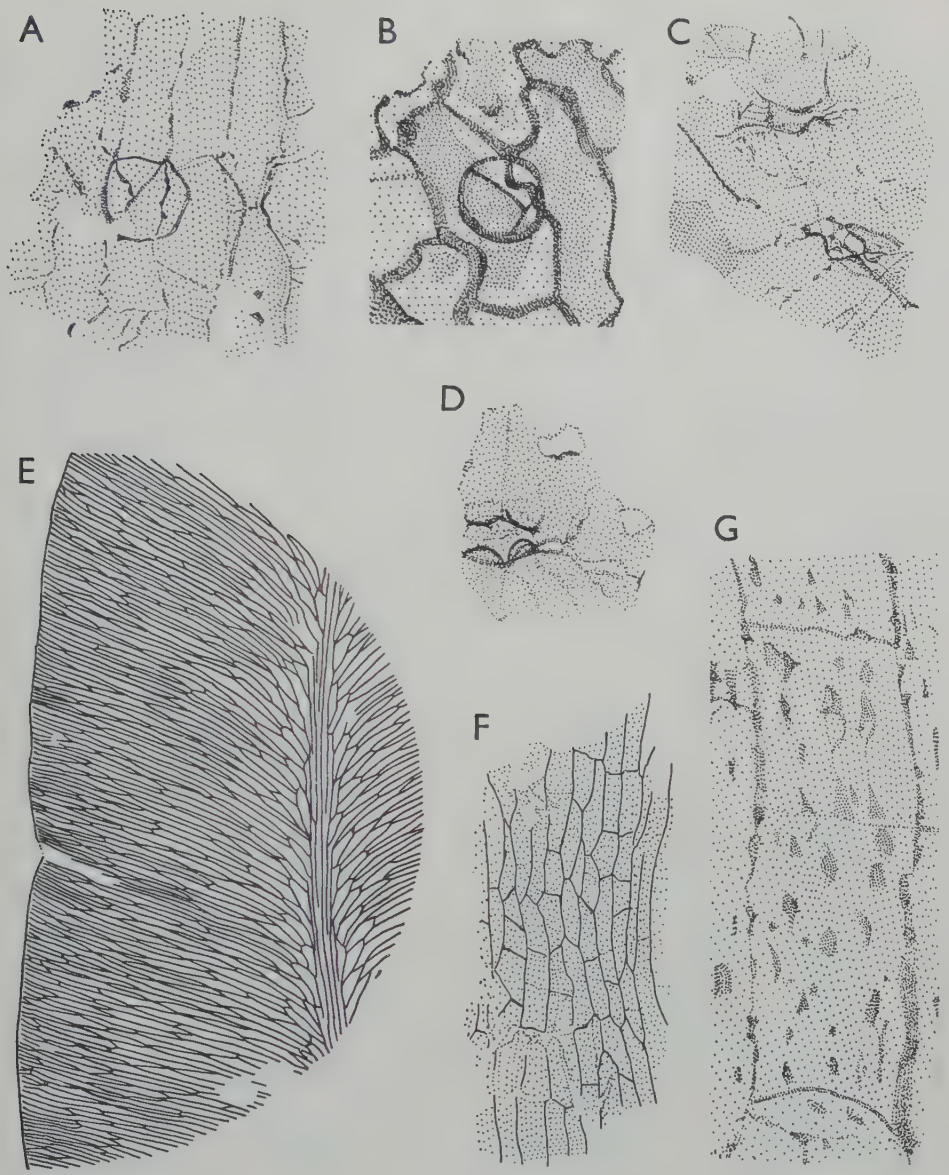

FIG. 4. *Glossopteris hispida* n. sp. A, lower cuticle showing hair base. V. 34451*a*. × 400. B, lower epidermis showing three-celled hair base. V.34450*a*. × 400. C, D. fragments of lower cuticle showing stomata. V.34452. × 400. E, middle part of leaf showing venation and lobed margin. V.34451. × 2. F, upper cuticle showing elongated cells in rows. V.34451*b*. × 125. G, a cell from F further magnified to show its numerous papillae (the small dots represent the substance of the cuticle). V.34451*b*. × 800.

FIG. 5. *Glossopteris hispida* n. sp. A, hairs from matrix in contact with lower side of leaf. B, lower epidermis of midrib showing trichome bases. C, lower epidermis of stomatiferous area between two veins near midrib showing straight-walled cells, stomata and hair bases. The rows of elongated cells in the middle are above a fibre. D, lower epidermis of a mesh away from midrib showing sinuous-walled cells. The elongated cells on the right are above a fibre (see Text-fig. 6 for details of stomata and cells). All from Holotype (V.34450*a*). × 125.

to the veins (about 39–52 μ long × 13–24 μ wide), and palisade mesophyll cells (about 18–30 μ wide) also showing a few isolated fibres running parallel to veins in vein meshes.

Upper cuticle of lamina about 2 μ thick, showing rectangular or polygonal cells. Cells short or frequently elongated in the direction of veins and tending to be in rows parallel to veins, lateral and end walls straight, thin, often obscure. Surface wall with numerous small papillae which tend to be in longitudinal rows, sometimes cell surface irregularly mottled. Cells typically about 30 μ × 57 μ.

Upper cuticle of midrib showing rectangular cells, short or longitudinally elongated, tending to be in longitudinal rows. Surface mottled, papillae absent. Stomata and trichomes absent on the upper side.

Lower epidermis of lamina showing frequent trichomes and trichome bases both along veins and between them, stomata present in areas between veins. Cells in meshes near midrib almost straight walled, polygonal, isodiametric or elongated in various directions; cells in meshes away from midrib irregularly shaped, often more or less elongated in the direction of the veins, cells averaging about 46 μ wide × 62 μ long; lateral (anticlinal) walls slightly to markedly sinuous. Cells above veins and sometimes above fibres in meshes, straight walled, narrow and elongated in the direction of the veins. Lateral walls of lower epidermal cells about 3 μ thick, sometimes unequally thickened. Surface of cells very finely mottled, usually without any papillae.

Lower epidermis of midrib with longitudinally elongated or short, polygonal or rectangular cells, lateral walls straight, about 6 μ thick, surface wall finely mottled, trichomes and trichome bases present, stomata absent.

Trichome bases composed of a single oval or rounded cell, or two or three cells, commonly overlapping a number of ordinary epidermal cells but occasionally overlying a single cell. Trichomes simple, three- to six-celled, tapering, cells short or long, apex of end cell acutely pointed. Trichomes pointing in different directions but usually outwards and backwards on the midrib and backwards on the lamina.

Concentration of stomata about 70 per sq. mm., orientation irregular. Stomata haplocheilic, monocyclic. Guard cells averaging 49 μ long × 21 μ wide, partly overhung by subsidiary cells and their papillae or occasionally exposed. Subsidiary cells 4–6, irregular or forming an irregular ring, like ordinary epidermal cells in shape and size but usually with a prominent thick-walled hollow papilla pointing over the stomatal pit or with a thickened rim towards stomatal aperture. Polar subsidiary cells like lateral ones.

Lower cuticle delicate (about 1 μ thick), cell walls often obscure, thin and straight; surface wall smooth or granular, papillae absent in ordinary epidermal cells but present in subsidiary cells. Lower cuticle otherwise like lower epidermis.

Holotype. Brit. Mus. (N.H.) Palaeont. Dept. no. V.34450.

Locality and horizon. Mhukura Coalfield, Songea District, Tanganyika; Ecca Series (" Upper Coal Measures ").

Description. The material consists of four good specimens and a few small fragments. In two of the leaves the lamina is torn (see Text-figs. 1, F and 4, E).

The veins and the midrib show abundant scalariform tracheids like those of *G.*

fibrosa. In the epidermal pulls the guard cells show lateral and polar lignine lamellae. These dissolve on maceration. Some cells of the lower epidermis show a dark inner area, slightly smaller than their lumen, which looks like their contracted contents. Dark spots, resembling median papillae, are also seen in a few cells of the lower epidermis. The spot is often placed near one end of the cell. No corresponding structures were observed in the lower cuticle and these spots may be extraneous particles.

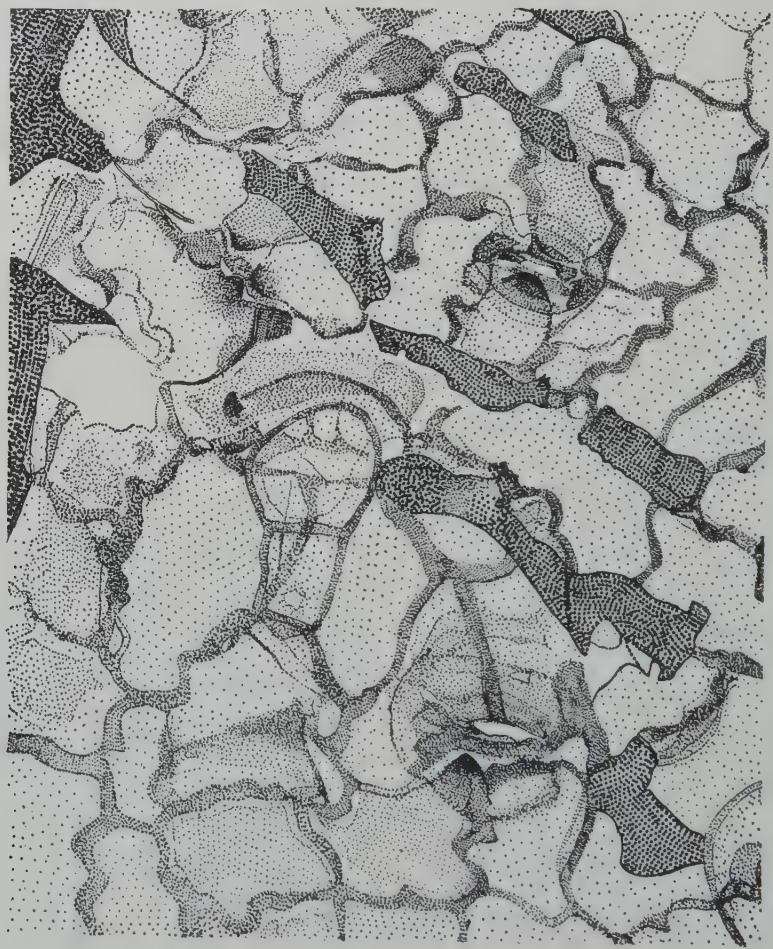

FIG. 6. *Glossopteris hispida* n. sp. Part of Text-fig. 5, D further enlarged to show details of stomata and two-celled hair base (see also Pl. 20, fig. 2). × 400.

Two-winged pollen grains of varying sizes are frequently seen overlying the cuticle.

COMPARISON. *G. hispida* agrees with *G. fibrosa* in venation and in the fibres between the veins. Though the vein meshes are usually of similar size, no specimens of *G. hispida* are known with meshes as narrow as in some of *G. fibrosa*.

The conspicous difference is in the hairs on the underside of *G. hispida* (none in *G. fibrosa*). These are seen clearly when the matrix in contact with the underside of the leaf is moistened with oil ; their bases are also visible in the epidermis and the cuticle. In *G. fibrosa* the cuticle is rather thicker and usually with clearly marked cell outlines, the cuticle of *G. hispida* is thin and the cell outlines obscure. The cells of the lower epidermis in *G. hispida* have sinuous walls (except over veins and midrib and in meshes near midrib), in *G. fibrosa* they are always almost straight. In *G. fibrosa* the stomata are partly amphicyclic, in *G. hispida* monocyclic. There may be other differences between the two species but their constancy is unknown.

Glossopteris leaves with rather similar veins but whose fine details are unknown have been described under such names as *G. ampla, G. musaefolia, G. indica, G. browniana, G. damudica,* and others. I am unable to distinguish any difference between them. A celloidin pull from one of the original specimens of *G. ampla* Dana sent to me by Dr. S. H. Mamay did at least differ in possessing no fibres. I also examined the types of *G. indica* Göppert (*G. browniana,* var. *indica,* Brongniart, 1828, pl. 62, fig. 2) consisting of two separate pieces (No. 506) in the Paris Museum of Natural History ; *G. musaefolia* Bunbury (V.19621 and also syntype material), and a specimen attributed to *G. damudica* var. *stenoneura* (V.19577) by Feistmantel (1889, pl. 4, fig. 7) in the Palaeontological Department of the British Museum (Natural History). They all differ from *G. hispida* in lacking impressions of fibres in vein meshes (the original leaf substance is not preserved).

Glossopteris colpodes n. sp.

(Pl. 19, fig. 2 ; Text-figs. 7–9)

Diagnosis. Leaf elongated (length unknown), average width in middle region about 6 cm. (extremes 4·5–7·5 cm.) basal part tapering with margins approaching midrib at an angle of 10°; apex more obtuse, margins approaching midrib at an angle of 30°. Midrib up to 0·4 cm. wide below, showing numerous longitudinal strands and often small lumps in lower parts, fewer strands and lumps above. Leaf margin entire, undulating or lobed, slightly thickened.

Veins arising from midrib at a small angle but soon bending outwards for about 1 cm. and then continuing at an angle of 45°–65° to midrib (in extreme specimen 75°–80°). Concentration of veins (measured at right angles to majority of veins) 11–15 per cm. near midrib in lower and middle parts of leaf, increasing to about 20 per cm. near midrib in upper part. Near margins veins more crowded, about 30 per cm. (maximum about 36 per cm.). Veins usually up to 140 μ thick, prominent. Veins and midrib raised on the lower side of leaf and midrib also slightly depressed on the upper. Meshes average 4 mm. long (extremes 2–8 mm.) and 0·9 mm. wide (extremes 0·5–1·5 mm.) in lower and middle parts of leaf, longer and narrower in upper part, averaging 7 mm. × 0·5 mm.; ultimate meshes near margin often short and narrow. Veins usually bending slightly forwards at margin.

Upper epidermis of lamina without stomata or trichomes. Cells over veins

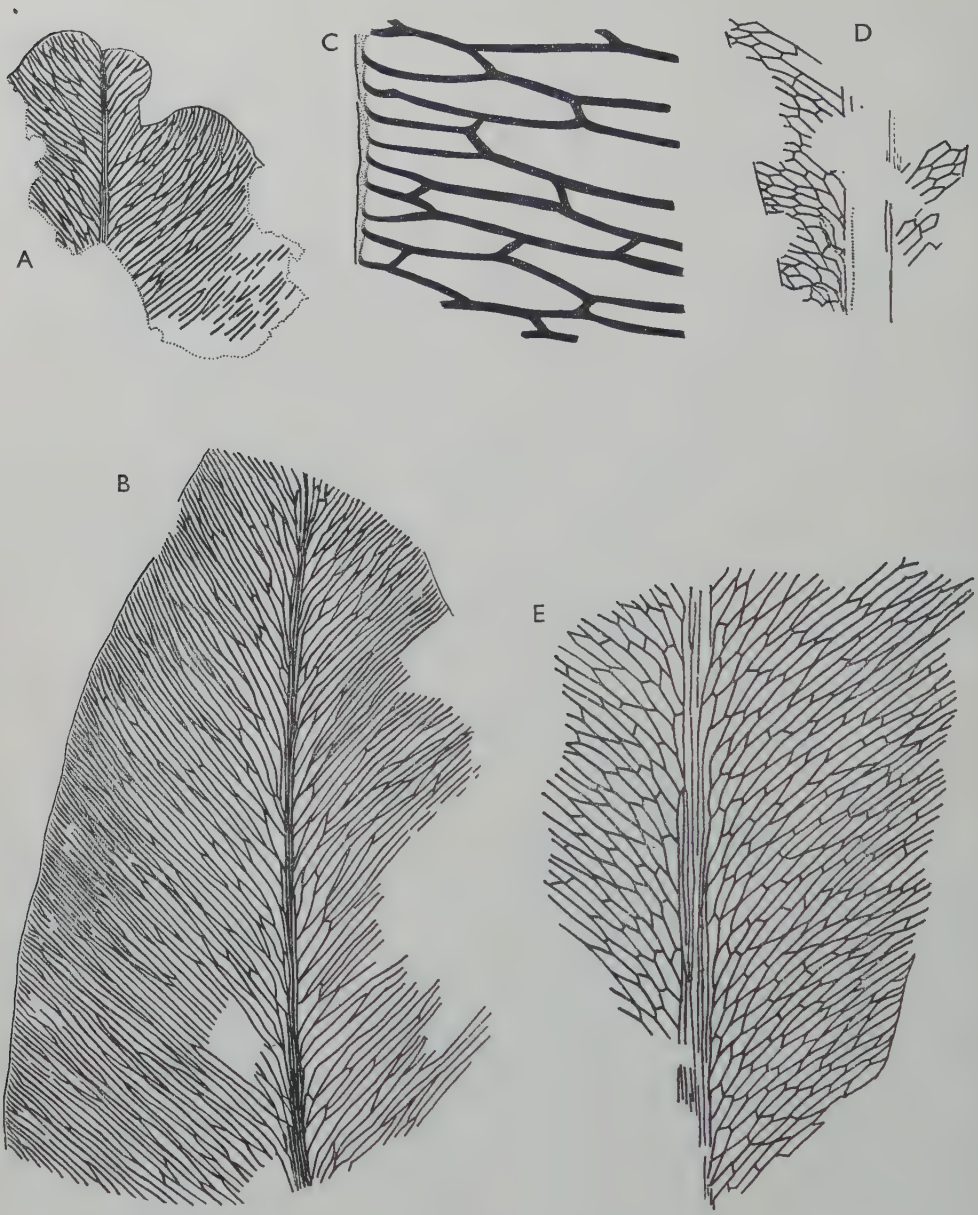

FIG. 7. *Glossopteris colpodes* n. sp. A, lobed apex with narrow elongate meshes. V.34462. × 2. B, apical part of leaf. V.34463. × 2. C, details of venation at margin of a leaf. V.34465. × 10. D, basal part of a leaf. V.34464. × 2. E, middle portion of leaf. Holotype, V.34461. × 2.

narrow, elongated, straight-walled. Cells between veins irregularly shaped or polygonal, short or elongated in various directions, averaging 66 μ long and 40 μ wide. Lateral (anticlinal) walls of cells about 3 μ thick, slightly to markedly sinuous, sometimes appearing nearly straight especially near midrib and margins. Cells at margin longitudinally elongated, nearly straight-walled. Surface of upper epidermal cells always mottled, most cells showing a median papilla about 6 μ wide. Cells over midrib in longitudinal rows, rectangular, short or elongated, lateral walls straight, papilla sometimes seen, trichomes absent.

Upper cuticle moderately thick (about 3 μ), cell outlines between veins obscurely marked, often appearing discontinuous but scarcely showing sinuous waves. Cell walls clearer over midrib and margins, straight or nearly straight but always appearing closely beaded. Papillae sometimes visible.

Lower epidermis of lamina showing narrow straight-walled cells above veins. Cells between veins elongated in various directions or isodiametric, averaging 69 $\mu \times 38$ μ, often irregularly shaped, lateral walls more or less sinuous, often unevenly thickened, but nearly straight near midrib and margins. Walls about 3 μ thick. Surface of cells always mottled and often showing a median papilla. Trichomes absent.

Stomata frequent between veins, often unevenly distributed, concentration about 66 per sq. mm., orientation varied. Stomata haplocheilic, monocyclic, occasionally incompletely amphicyclic. Guard cells about 65 $\mu \times 25$ μ, sunken, frequently entirely covered by 4–8 subsidiary cells and their papillae, except sometimes from a region near aperture. Subsidiary cells irregular or forming an irregular ring, polar cells resembling lateral ones, size of subsidiary cells almost as large as that of other epidermal cells, but surface sometimes thicker ; each subsidiary cell usually with a large hollow but thick-walled papilla pointing over the stomatal pit (papillae often overlapping and completely concealing the stomatal aperture) or papilla pointing upwards. Sometimes a second median papilla also present in subsidiary cells. Encircling cells unspecialized but often tangentially elongated.

Lower cuticle of lamina thin (1–2 μ thick), cell walls between veins faintly marked, usually interrupted and appearing nearly straight but never showing well-marked waves, occasionally walls almost straight. Cell walls over veins more distinct, straight, almost continuous but closely beaded. Papilla and surface mottling often visible. Surface occasionally showing radiating striations extending over several cells. Guard cell outlines clearly marked at the poles but faint on the sides.

Lower cuticle of midrib with short or long polygonal cells arranged in longitudinal rows. Lateral walls straight, surface mottled. Papillae often absent. Stomata and trichomes absent.

HOLOTYPE. Brit. Mus. (N.H.) Palaeont. Dept. no. V.34461.

LOCALITY AND HORIZON. Mhukuru Coalfield, Songea District, Tanganyika ; Ecca Series (" Upper Coal Measures ").

DESCRIPTION. Sixty-seven fragments were attributed to *G. colpodes*. The difference between the venation in the apical and the basal regions is considerable. These were identified with one another because of their lack of fibres between veins

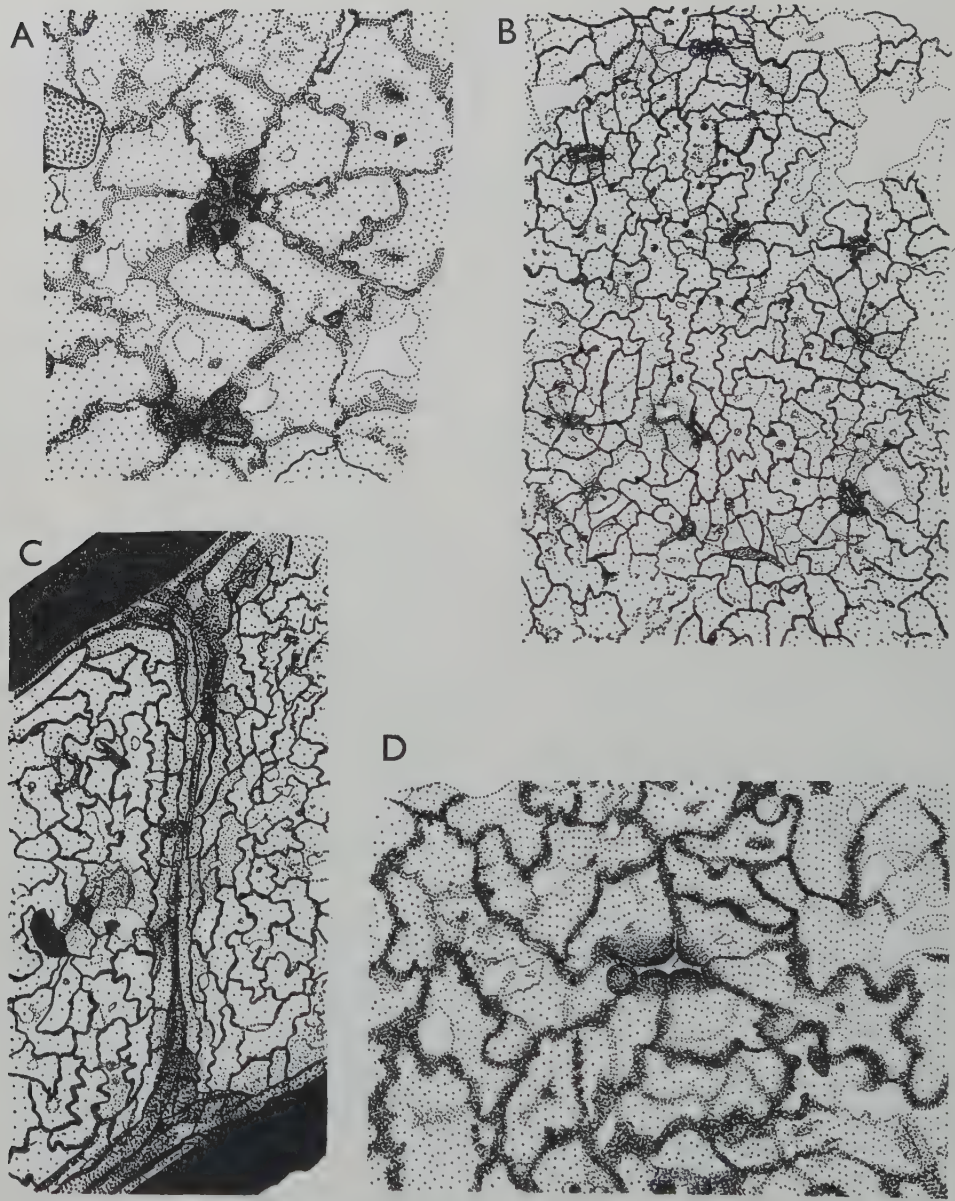

FIG. 8. *Glossopteris colpodes* n. sp. A, two protected stomata. V.34466*a*. × 400. B, lower epidermis of stomatiferous area between two veins. V.34466*b*. × 125. C, lower epidermis. V.34466*b*. × 125. D, relatively exposed stoma from B. × 125.

and also because of their agreement in epidermal or cuticular structure. Fourteen specimens show epidermal cells of the upper or the lower sides and these have sinuous walls, except above the veins and the midrib and in meshes near the midrib and the margins. The other specimens were too thick to show the epidermal cells but they all gave cuticles which showed the characteristic cells with very obscurely marked walls which appear more or less straight but discontinuous (see Text-figs. 9, A; 9, D).

Several epidermal specimens show structures not mentioned in the diagnosis. When sufficiently exposed, the guard cells show lateral and polar lignine lamellae of the Gymnosperm type (these are unrepresented in the cuticle). Some pulls show circles abut 30 μ wide representing flattened palisade cells; others show less distinct spongy mesophyll cells often elongated transversely to the veins. At a few points in the pulls the veins and the midrib show scalariform tracheids.

The only specimen showing the apex was unfortunately rubbed and damaged. The lamina is lobed (Text-fig. 7, A). There is nothing to show whether this is normal.

Two-winged pollen grains of various sizes ranging between 40–100 μ across are frequently found sticking to the epidermis or cuticle of either side.

Comparison. *G. colpodes* is distinguished from *G. fibrosa* and *G. hispida* by the lack of fibres between the veins and in the lower parts by its wider meshes. The epidermal cells in *G. fibrosa* are never sinuous walled (markedly sinuous in *G. colpodes* except above the veins and the midrib and in the meshes near the midrib and the margins). *Glossopteris* sp. A may have veins as wide as those in *G. colpodes* and also lacks fibres in meshes but differs in the complete absence of sinuous-walled cells. The lower epidermis of *G. hispida* resembles that of *G. colpodes* in having sinuous-walled cells but differs in having trichomes (in *G. colpodes* trichomes are absent).

Among *Glossopteris* leaves of comparable venation are: Dana's Australian leaves of *G. reticulum* and *G. elongata* (Dana 1849), ? *Dictyopteris simplex* Tate (*G. Tatei* Feistmantel, 1889) from S. Africa (Tate, 1867), Feistmantel's Indian leaves of *G. retifera* and *G. conspicua* (Feistmantel, 1880; 1881; 1886) and various other specimens referred to them by Feistmantel and others, *G. brancai* Gothan (1914), from Portuguese East Africa, and some specimens assigned to *G. browniana* by Arber, (1905*a*), Walton (1929) and others. Most of them differ from *G. colpodes* in the size of meshes and their fine details are unknown (see table II). However, a specimen assigned to *G. browniana* by Arber (1905*a*, : 56, pl. 3, fig. 2) and two others figured by Walton (1929 : 70, pl. C, figs. 21, 22) as *G. cf. browniana* and *G. retifera* respectively are very similar to *G. colpodes* in their venation but like the rest their epidermal or cuticular structure is unknown.

I have also been able to examine some wide meshed undescribed Indian leaves at the Oxford University Museum and an Australian specimen at the British Museum. These yielded pulls showing epidermal cells and stomata very similar to those of *G. colpodes*. The Indian leaves have veins at about the same concentration as in *G. colpodes* (about 10–12 veins per cm. near midrib) and may belong to the same species. The meshes of the Australian leaf are much wider (up to 2·5 mm. wide, concentration of veins about 8 per cm. in lower part) and are therefore outside the range observed in the present material of *G. colpodes*.

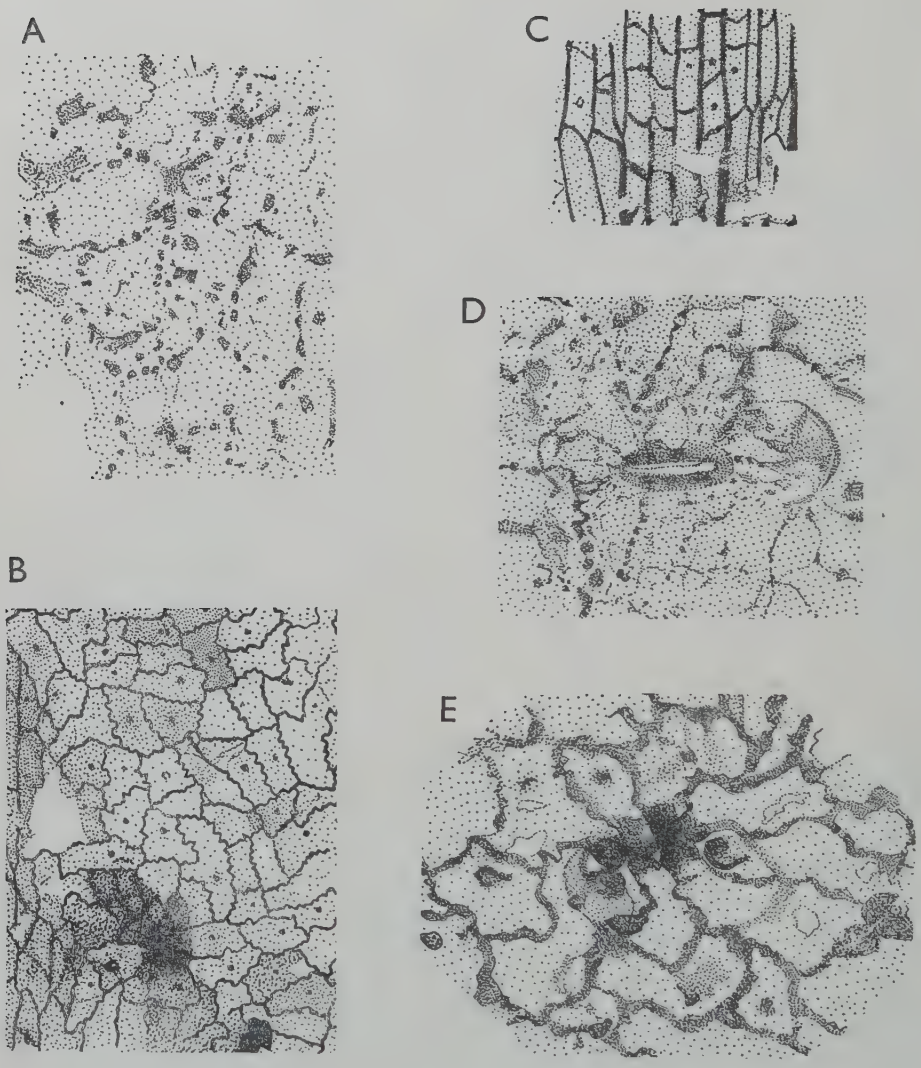

FIG. 9. *Glossopteris colpodes* n. sp. A, upper cuticle as seen under phase contrast microscope. V.34466*c*. × 400. B, upper epidermis showing sinuous-walled cells between veins and straight-walled cells above a vein. V.34466*d*. × 125. C, epidermis over midrib. V.34466*d*. × 125. D, lower cuticle showing a stoma as seen under phase contrast microscope. V.34466*e*. × 800. E, lower epidermis showing a stoma with a ring of eight subsidiary cells and a few encircling cells. V.34466*a*. × 400.

TABLE II.—*Comparison of Certain* Glossopteris *Leaves with Wide Vein Meshes*

Material	Concentration of veins per cm.	Character of meshes	Angle of veins to midrib after 1 cm.	Walls of epidermal cells
1. *G. colpodes* . . *Loc.* Mhukuru Coalfield, Tanganyika, (many specimens)	Near midrib 11–15 in middle and lower parts; up to 20 towards apex; near margin up to 36	Short and wide near midrib and base, elongated towards apex and margin	45°–65°	Sinuous.
2. *Glossopteris* sp. A. . *Loc.* Mhukuru Coalfield, Tanganyika (2 specimens)	Near midrib 27–30; near margins up to 36 (about 20 in second specimen)	Elongated but often shorter near midrib and margins	40°–50°	Straight.
3. *Glossopteris* sp. Nos. FY 14, 16–21, Oxford University Museum. *Loc.* Raniganj Coalfield, Burdwan, India (15 specimens)	Near midrib 10–12 (veins ill-preserved near margins)	Shorter and wider near midrib, elongated elsewhere	60°–70°	Sinuous.
4. *Glossopteris* sp. No. V.34491 *Loc.* Newcastle, N.S.W. (1 specimen)	Near midrib about 9; near margin about 15 in lower parts of leaf	Ditto	80°–85°	,,
5. *G. browniana* (Arber, 1905*a*: 56, pl. 3, fig. 2. No. V.7207. *Loc.* Port Stephens, N.S.W.	Near midrib 14–16 up to 21 near margin (only middle part known)	Ditto	60°–70°	Unknown.
6. *G.* cf. *browniana* (Walton, 1929: 70, pl. C, fig. 21). No. V.20780. *Loc.* Wankie Coalfield, S. Rhodesia	Near midrib up to 15; up to 20 near margin in lower and middle parts. Upper part of leaf unknown	Short and wide near midrib in upper part, elongated elsewhere; almost uniformly short towards base	50°–60°	,,
7. *G. retifera.* (Walton, 1929: 70, pl. C, fig. 22). No. V.20781. *Loc.* Wankie Coalfield, S. Rhodesia	Near midrib 11–16, about 20 near margin (only basal part of leaf known)	Almost uniformly short and wide	50°–60°	,,
8. *G. retifera* (Feistmantel, 1880: 103, pl. 28A, figs. 2, 7, 10; pl. 41A. 1886, pl. 4A, fig. 1). *Loc.* Raniganj Coalfield, Ramkola Coalfield, Nakori River, nr. Gai Nagar, Ganespur River, India	9–14 all over lamina (from figs.)	Ditto	50°–60°	,,

Table II.—*continued*

Material	Concentration of veins per cm.	Character of meshes	Angle of veins to midrib after 1 cm.	Walls of epidermal cells
9. *G.retifera* (Plumstead, 1952 : 300, pl. 49, fig. 5, pl. 51, figs. 1–6, text-fig. 6. *Loc.* Leeukuil, Vereeniging, Transvaal, S. Africa	4 near midrib, 21 near margin in upper part (from description) but 9–12 near midrib, 21 near margin, in Plumstead, 1956, pl. 12, fig. 2	Short and wide near midrib and base, elongated in upper part	"Almost 90° "	Unknown
10. ? *Dictyopteris simplex* (Tate, 1867 : 141, pl. 6, fig. 6 — *G. tatei* Feistmantel, 1889 : 44, pl. 4, fig. 8). No. V.19579. *Loc.* Bloemkop, S. Africa	7–10 near midrib, about 12 approx. 2 cm. from midrib. Margin not preserved	Short and wide near midrib, elongated, elsewhere.	70°–80°	,,
11. *G. brancai* (Gothan, 1914 : 13, pl. 1, figs. 2, 3). *Loc.* Tete, Portuguese East Africa	4–6 near midrib, 10–12 near margin in upper and middle part (from figs.)	Ditto	85°–90°	,,
12. *G. conspicua* (Arber, 1905*a* : 87, pl. 3, fig. 3). No. V.2465. *Loc.* Mill River Drift, Orange River Colony.	9–16 near midrib in various leaves in the slab	Ditto	50°–70°	,,
13. *G. conspicua* (Feistmantel, 1881 : 104, pl. 28A. figs. 1, 5, 6, 8, 9). *Loc.* Raniganj, Karanpura, and Auranga Coalfields, India.	7–9 all over lamina (from figs.)	Elongated	50°–60°	,,
14. *G. reticulum* (Dana, 1849 : 717, pl. 13, fig. 2). *Loc.* Newcastle, N.SW.	6 near midrib in middle part, 12 near midrib towards apex and near margin. Only upper part of leaf known (from description and fig.)	,,	"About 65° "	,,
15. *G. elongata* (Dana, 1849 : 718, pl. 13, fig. 4). *Loc.* Newcastle, N.S.W.	7–11 below. Only basal part of leaf known (from description and fig.)	Almost uniformly short and wide	"60° or more "	,,

Glossopteris sp. A

(Text-fig. 10)

Locality and horizon. Mhukuru Coalfield, Songea District, Tanganyika; Ecca Series (" Upper Coal Measures ").

Only two specimens were recognized. The largest fragment (V.34467) is shown in Text-fig. 10, E, where all the details clearly visible are accurately represented. The second specimen (V.34493), a fragment with neither midrib nor margin has slightly wider meshes, up to 1 mm. wide. The veins are sinuous but since the epidermal cells show straight veins I have no doubt that the veins have been displaced during preservation.

In both specimens the substance of the lamina is thin. In neither are there any fibres in the vein meshes. The cuticle of both leaves was prepared but the figures are all from the leaf shown in Text-fig. 10, E.

The upper cuticle of the lamina is about 3 μ thick. The cell outlines are clearly marked as shown in Text-fig. 10, C. Lateral walls of cells are thin but have a border on either side (Text-fig. 10, D). The cells tend to be in rows parallel to the veins. The cells above the veins could not be seen in this specimen but in the second specimen they are narrower and more elongated. Stomata are absent.

The lower cuticle is thinner (about 1–2 μ thick). The cell outlines are moderately clear (Text-fig. 10, A). Lateral walls of cells are straight. The cell surface usually shows a median papilla. The cells above the veins are narrow and elongated in the direction of the veins, those between the veins are usually isodiametric or elongated in various directions. Stomata are confined to areas between the veins. Trichomes are absent.

The stomata are haplocheilic and possibly partly amphicyclic. The guard cells are hidden by a ring of five or more subsidiary cells. Each subsidiary cell usually has a prominent thickened papilla covering the stomatal aperture. The cells regarded as encircling cells resemble ordinary epidermal cells but are often tangentially elongated.

The cuticle in the second specimen is very similar but the papillae are very obscure.

Glossopteris sp. A resembles *G. fibrosa* in form, venation and cuticle. The only difference is in the isolated fibres which are here absent but conspicuous in *G. fibrosa*. It differs from *G. hispida* in lacking fibres, hairs and sinuous-walled cells. In the complete absence of sinuous-walled cells it differs also from *G. colpodes*.

It has not been named as a species because too little is known about it.

Genus ***RHABDOTAENIA*** nov.

Diagnosis. Leaf elongated, entire, with a strong midrib, lamina arising from the sides of the midrib, lateral veins arising at a wide angle or at a smaller angle but almost immediately bending outwards and crossing the lamina at a wide angle, lateral veins occasionally forked, anastomoses between lateral veins extremely rare. Stomata usually confined to areas between veins on lower epidermis, subsidiary

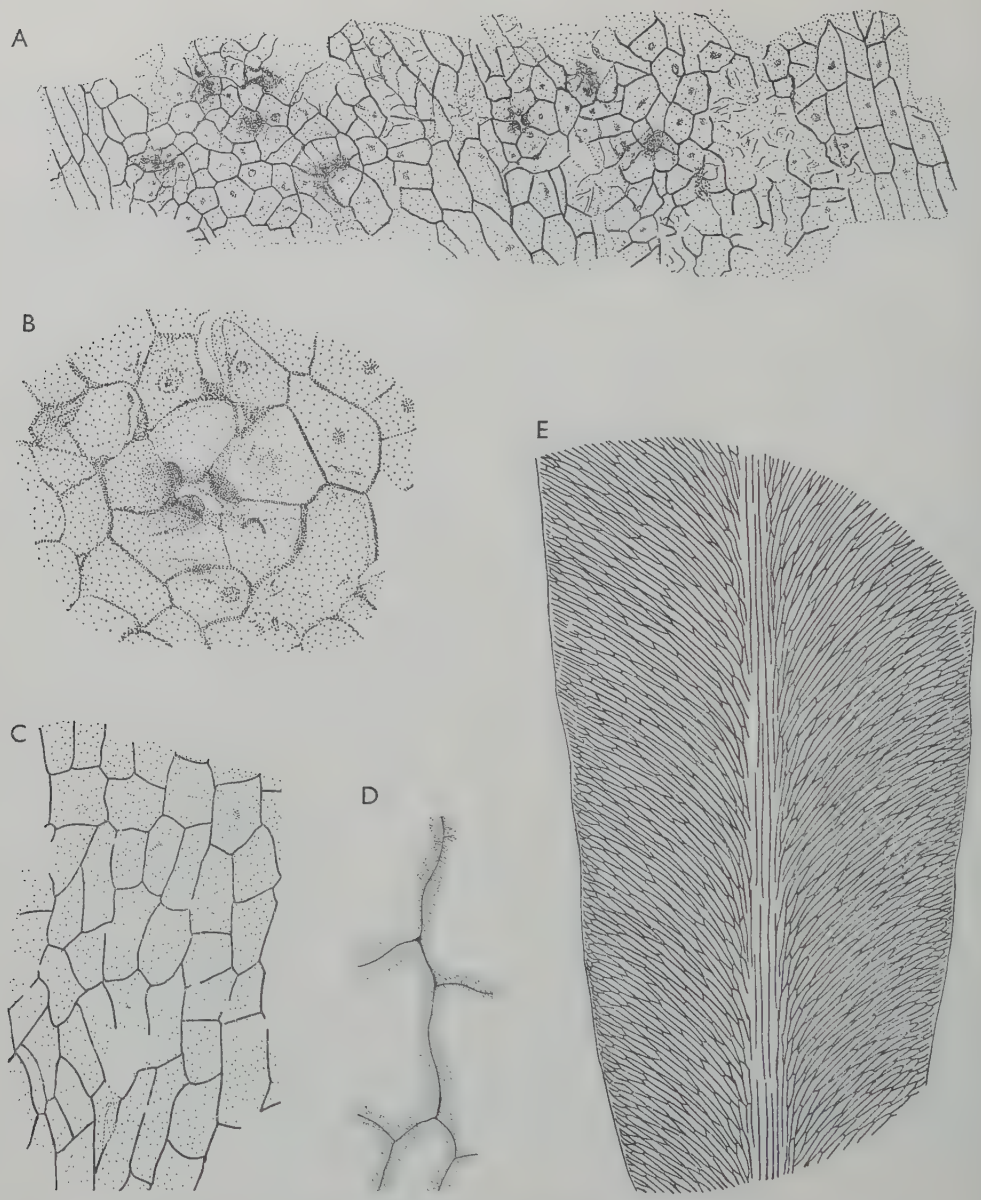

FIG. 10. *Glossopteris* sp.A. A, lower cuticle showing elongated cells above veins and stomatiferous areas between them. V.34467*a*. × 125. B, stoma from A. × 400. C, upper cuticle showing cells in rows parallel to veins. V.34467*a*. × 125. D, part of C more magnified to show bordered walls. × 400. E, middle part of leaf showing venation. V.34467. × 2.

cells haplocheilic, irregular, not forming a definite ring, guard cells exposed or covered by subsidiary cell papillae not situated in a pit. Cuticle rather thin.

TYPE SPECIES. *Rhabdotaenia danaeoides* (Royle) n. comb.

DISCUSSION AND COMPARISON. *Rhabdotaenia* is made for certain fronds of taeniopterid form of which the cuticular structure is known. Among such fronds with haplocheilic stomata are *Bjuvea* Florin (1933 : 48) in which the subsidiary cells are in a rather definite ring and form a pit above the guard cells, and *Doratophyllum* Harris (1932 : 36) where they form a perfect ring arching over the guard cells as a cone. The irregularity of the subsidiary cells distinguishes *Rhabdotaenia*.

The mode of origin of the lamina from the sides of the midrib may be important. In *R. danaeoides* and in *R. harkini* there is no very sharp border to the midrib, certainly no fold such as is seen in *Taeniopteris vittata* where the lamina arises rather above the middle of the rachis and a good deal more rachis is seen from below than from above. In *Nilssonia* it differs even more, arising from the top of the rachis. The precise level of origin in *Doratophyllum* and *Bjuvea* has not been discussed. In *Glossopteris*, from my own observations, the origin of the lamina is purely lateral ; the midrib, however, being slightly depressed on the upperside and prominent below may occasionally show folds at the sides but otherwise it grades imperceptibly into the lamina. The epidermal structure of *Rhabdotaenia* also resembles that of *Glossopteris* and it may be that the two genera are naturally related.

Other genera which may be mentioned are the ill-defined *Macrotaeniopteris* (type *M. major*) which proves to be a Bennettitalean leaf like several other species and may be included in *Nilssoniopteris*, and *Palaeovittaria* (Feistmantel, 1876 : 368, pl. 19, figs. 3, 3*a*, 4, 4*a* ; Zeiller, 1902*a* : 81, pl. 16, fig. 1) which differs in the small angle of the veins from the midrib.

Rhabdotaenia danaeoides (Royle) n. comb.

(Text-fig. 11)

1833. *Glossopteris danaeoides* Royle, p. 29, pl. 2, fig. 9.
1836. *Aspidites danaeoides* (Royle) Goeppert, p. 352.
1850. *Pecopteris danaeoides* (Royle) Unger, p. 170.
1901. *Macrotaeniopteris danaeoides* (Royle) Arber, p. 548 (pars).
1905*a*. *Taeniopteris danaeoides* (Royle) Arber, p. 121, pl. 5, fig. 1.

Similar leaves but with finer details unknown :

1850. *Taeniopteris danaeoides* (Royle) : McClelland, p. 56 pl. 15, fig. 1.
1876. *Taeniopteris danaeoides* (Royle) : Feistmantel, p. 74.
1876*a*. *Macrotaeniopteris danaeoides* (Royle) Feistmantel, p. 137.
1876*b*. *Macroteniopteris danaeoides* (Royle) : Feistmantel, p. 305, pl. 19, figs. 1, 2 ; pl. 21, fig. 1.
1880. *Macrotaeniopteris danaeoides* (Royle) : Feistmantel, p. 88, pl. 20*a*, figs. 1, 2.
1886. *Macrotaeniopteris danaeoides* (Royle) : Feistmantel, p. 24, pl. 4*a*, figs. 2, 3.
1893. *Macrotaeniopteris danaeoides* (Royle) : Oldham, pl. 2.
1905*a*. *Taeniopteris danaeoides* (Royle) : Arber, p. 121 (pars).

EMENDED DIAGNOSIS. Leaf oval-oblong, widest in the middle region, typically 5–7 cm. wide, length possibly about 20 cm.; petiolate. Midrib up to 3 mm. wide

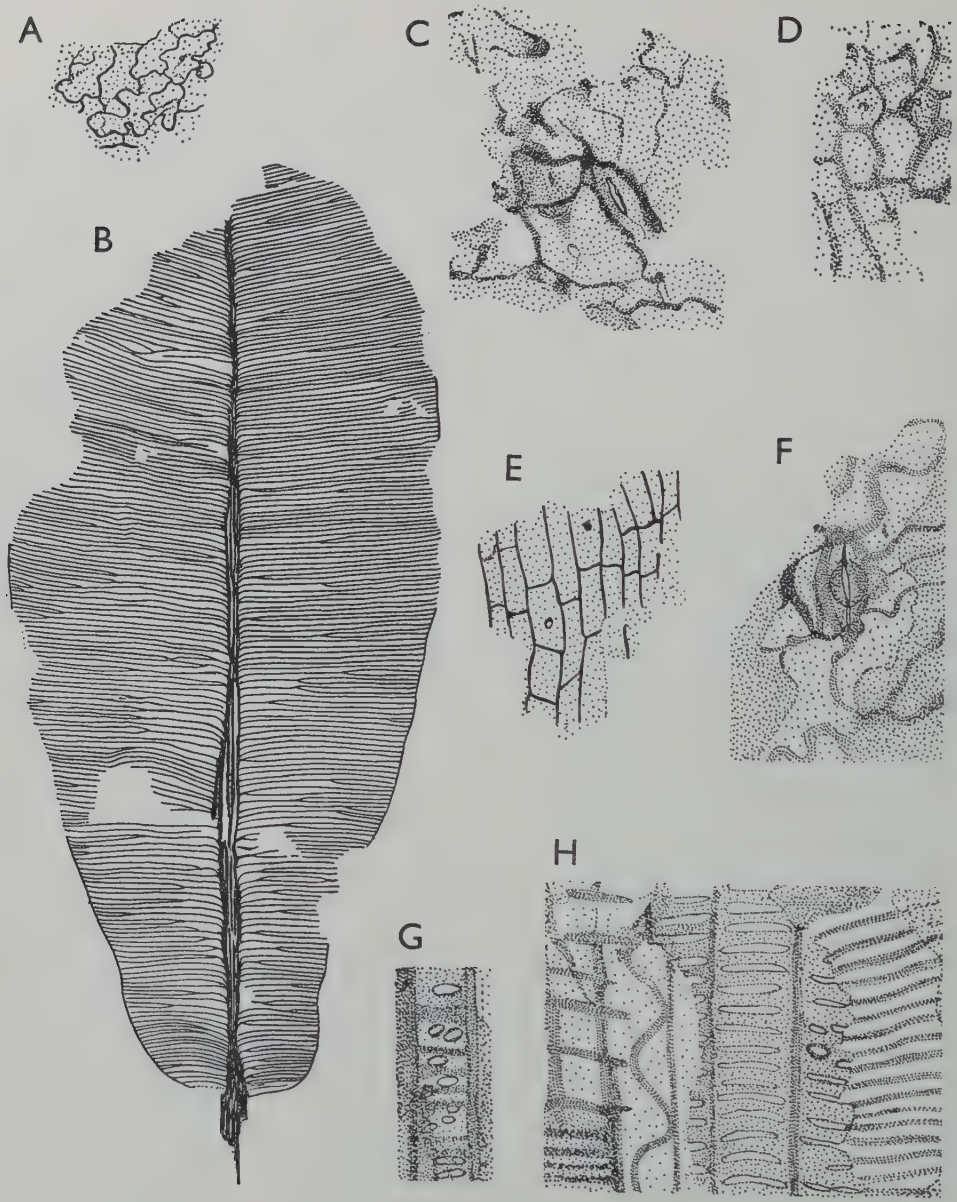

FIG. 11. *Rhabdotaenia danaeoides* (Royle). A, sinuous-walled cells of lower epidermis between veins. V.19598*a*. × 125. B, leaf showing venation. Neotype, V.4191. × 1. C, stoma showing exposed guard cells. V.19598*b*. × 400. D, upper epidermis showing straight-walled cells. V.19598*a*. × 125. E, epidermis of midrib. V.4191*a*. × 125. F, stoma showing lateral lignine lamellae of guard cells. V.19598*a*. × 400. G, tracheid showing both bordered pits and transverse bars, from midrib. V.19598*c*. × 800. H, xylem showing spiral, scalariform and pitted tracheids from midrib. V.19598*c*. × 800.

below, narrower towards the apex, showing numerous longitudinal strands near leaf base, fewer above. Margins entire or slightly undulate. Base more or less abruptly contracted.

Lateral veins parallel, arising at right angles to the midrib or at a smaller angle and almost immediately arching outwards and running at about 90° to midrib. About one-third of lateral veins forked once, rest unbranched. Twice forked veins very rare. Concentration of veins 12–16 per cm. near midrib, 15–20 per cm. near margins.

Upper epidermis of lamina probably without stomata. Cells between veins appearing polygonal with almost straight thick side-walls. Cells tending to be arranged in rows parallel to the side veins. Cells above veins narrower. Upper cuticle rather thick, like upper epidermis, surface showing longitudinal striations.

Upper and lower epidermis of midrib showing straight-walled rectangular cells tending to be arranged in longitudinal rows. Surface sometimes showing longitudinal striations, median papilla occasionally present, stomata absent.

Lower epidermis of lamina thinner than upper, stomatiferous. Cells between veins irregularly shaped, typically about 40 μ wide × 95 μ long, lateral (anticlinal) walls sinuous, about 3 μ thick, becoming gradually straight in the vicinity of midrib, surface occasionally showing striations and a rather obscure median papilla. Cells above veins straight-walled, rectangular, elongated in the direction of veins, surface sometimes with fine longitudinal striations.

Stomata present in areas between veins. Subsidiary cells haplocheilic, numerous (about seven), like ordinary cells, irregular, not forming a ring round guard cells, guard cells exposed, typically 8 μ × 32 μ.

Lower cuticle thin, walls obscure.

NEOTYPE. Brit. Mus. (N.H.) Palaeont. Dept. no. V.4191. Figured Royle (1833, pl. 2, fig. 9) and Arber (1905*a*, pl. 5, fig. 1).

PARATYPE. Brit. Mus. (N.H.) Palaeont. Dept. no. V.19598.

LOCALITY AND HORIZON. Burdwan Coalfield, India ; Permo-Carboniferous.

DESCRIPTION. The diagnosis is based on three leaves from Burdwan Coalfield, India, namely Royle's type (V.4191) and a block with two leaves (V.19598). They are very similar indeed but one of the leaves on V.19598 shows more of its petiole which is 3 cm. long.

Without examining the originals it is impossible to say which of Feistmantel's figured specimens belong to the same species ; all may well be the same. If so the species includes quite small oval leaves (4 cm. × 2·5 cm.) as well as much wider ones, up to 11 cm. wide and of unknown length.

Two cross connections occur between lateral veins in the neotype. Some guard cells show lateral lamellae. The midrib shows abundant tracheids, sides 14–30 μ wide. Some tracheids show spiral and annular thickenings but most are scalariform (Text-fig. 11, H). A few tracheids also show transverse bars between oval bordered pits (Text-fig. 11, G). There are in addition thick-walled elements showing usually sparsely distributed, small, oval or rounded pinhole-like pits and cells with no pits which may be tracheids or sclerenchyma.

Rhabdotaenia danaeoides is not the only species in the Lower Gondwana Coalfields

of India ; there is also *Macrotaeniopteris feddeni* figured by Feistmantel (1880 : 89, pl. 21A, fig. 3, pl. 22A, figs. 1–4 ; 1881 : 255, pl. 2, fig. 1 : 1882 : 31, pl. 21, fig. 5 ; 1886 : 24, pl. 1A, fig. 1). Dolianiti (1953 : 2, pls. 1, 2) has recently reported this species from Brazil.

Macrotaeniopteris feddeni is supposed to be distinguished chiefly by its more crowded veins and thinner midrib. However, several specimens referred to *M. feddeni* agree equally well with others referred to *Macrotaeniopteris danaeoides* e.g. one (Feistmantel, 1882, pl. 21, fig. 5) has as few as 11 veins per cm. according to the figure. I can see no difference in the midrib. No fine details are known. Clearly *M. feddeni* is not, at present, adequately distinguished.

The Brazilian leaf, however, has 25–35 veins per cm. and is clearly distinct from *Rhabdotaenia danaeoides*. The only other Lower Gondwana leaves are *Taeniopteris daintreei* McCoy (1875 : 15, pl. 14, fig. 1, 2), *Angiopteridium spathulatum* Etheridge (1901 : 72), *A.* cf. *mcclellandi* Feistmantel (1880 : 92, pl. 21A, figs. 4–7), *Taeniopteris criciumensis* Dolianiti (1953, pl. 3) and some imperfectly known *Taeniopteris* leaves which are all much narrower.

Rhabdotaenia danaeoides is compared with *R. harkini* below.

Rhabdotaenia harkini n. sp.

(Pl. 20, fig. 5 ; Text-figs. 12–14)

Diagnosis. Leaf about 6 cm. wide in widest part (presumably from middle region of leaf), length unknown. Midrib at least about 1 mm. wide below, narrower above. Margin entire, probably slightly undulate, very slightly converging towards apex. Lateral veins parallel, arising almost at right angles or at a smaller angle and almost immediately arching outwards and running at 80°–90° to midrib. Veins forked once or twice or unbranched, usually dichotomising near midrib and often elsewhere in the lamina. Cross connections between veins extremely rare. Some veins bent slightly forwards near margin but no marginal vein present.

Concentration of veins 15–18 per cm. near midrib, 23–28 per cm. near margin. Veins usually 145 μ thick but some veins up to 250 μ thick at base. Substance of lamina probably thin.

Upper epidermis of lamina without stomata. Cells between veins polygonal, isodiametric or elongated in various directions typically 60 μ × 45 μ wide, lateral (anticlinal) walls of cells straight, thick (up to 12 μ thick). Cells perhaps tending to be arranged in rows parallel to veins. Surface of cells finely mottled, papillae usually absent.

Upper cuticle about 2 μ thick, outlines of cells somewhat obscure, walls thin, otherwise like upper epidermis.

Lower epidermis of lamina thinner than upper, stomatiferous. Cells between veins irregularly shaped, isodiametric or elongated in various directions, typically about 90 μ long × 60 μ wide, lateral (anticlinal) walls of cells sinuous but gradually becoming straight near midrib. Cells near midrib and those in angles between branches of veins sometimes unusually large and with almost straight walls. Cells over veins narrow, elongated in the direction of veins, rectangular, lateral walls

straight. Lateral walls of lower epidermal cells often unevenly thickened, up to 3 μ thick. Cell surface usually showing a large thick-walled median papilla about 10–15 μ in diameter. Papillae in some ordinary epidermal cells and subsidiary cells of stomata (especially near imdrib) about 50 μ long, blunt and often with a

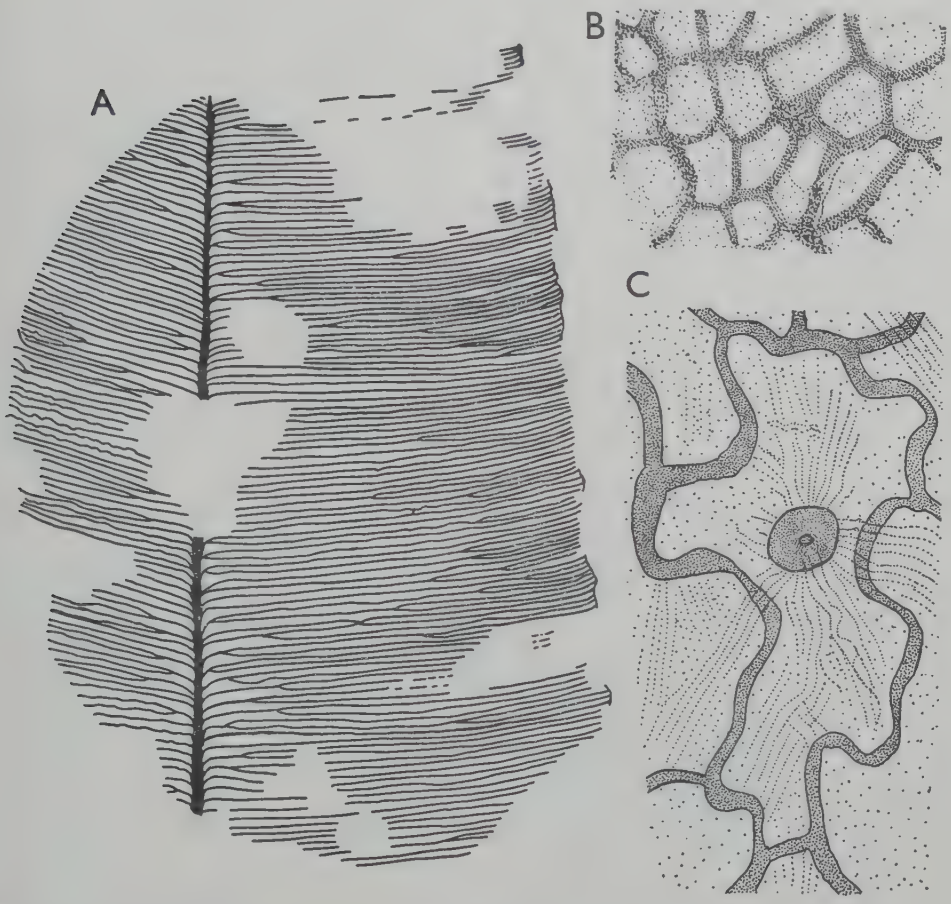

FIG. 12. *Rhabdotaenia harkini* n. sp. A, leaf showing venation. × 2. B, upper epidermis showing straight-walled polygonal cells. × 125. C, a cell of the lower epidermis from Text-fig. 13, B, showing the large median papilla and surface striations. × 800. All from the Holotype (V.34454).

rounded top. Cell surface sometimes showing a few ridges, but usually fine striations, radiating from the base of the papilla. Striations often running parallel and continuous between adjacent cells and intervening walls, but usually in no definite direction or arrangement in cells between veins, in cells above veins striations usually parallel and running in the direction of the veins. Striations running longitudinally along the surface of some laterally flattened papillae. Trichomes absent.

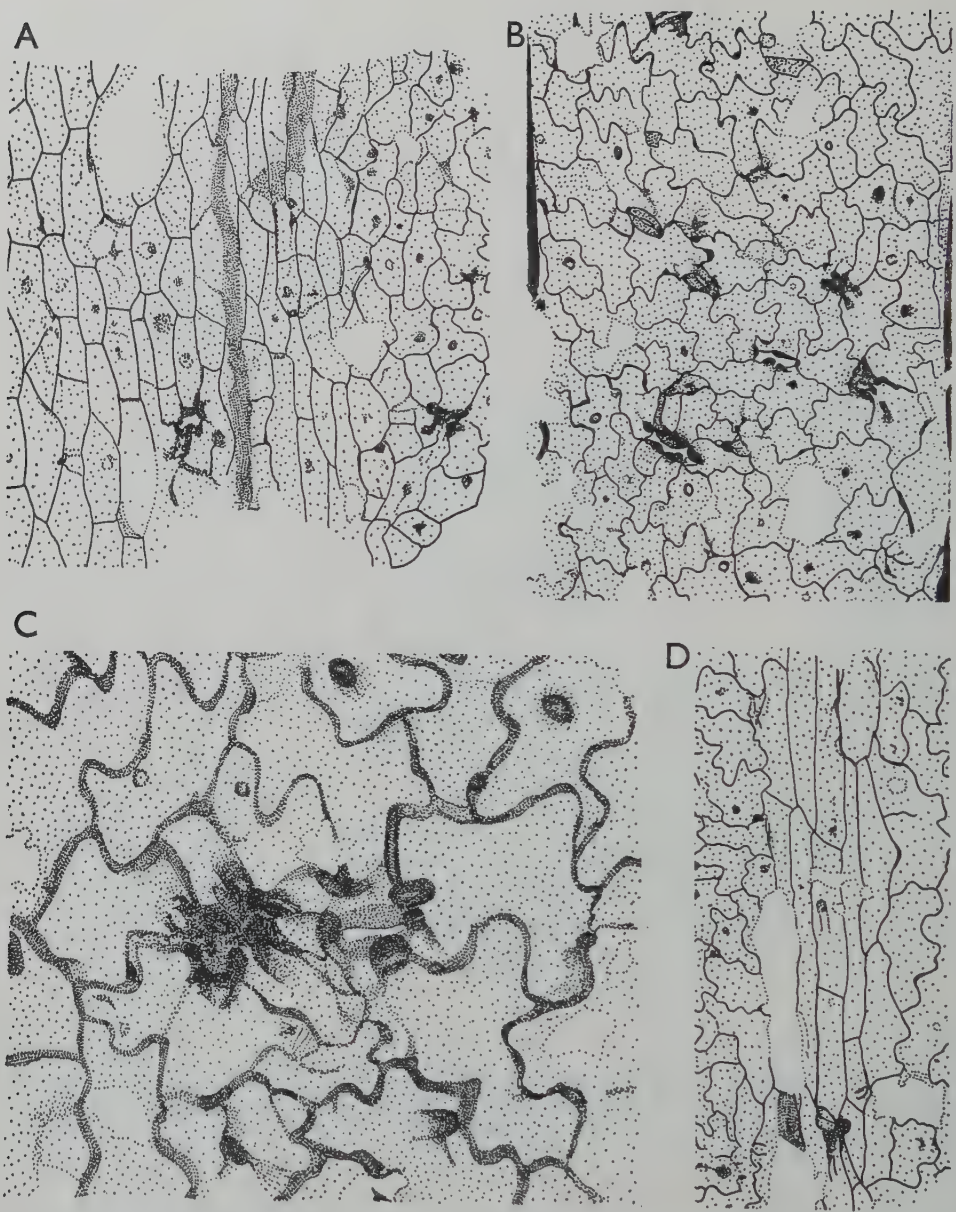

FIG. 13. *Rhabdotaenia harkini* n. sp. A, lower epidermis of midrib (on left) and stomatiferous area between bases of two lateral veins showing sinuous-walled cells on the right. × 125. B, stomatiferous area between two veins. × 125. C, two closely placed stomata, one (right) rather exposed, the other (left) protected by overlapping papillae. × 400. D, cells below vein (lower side). × 125. All from the Holotype (V.34454).

Stomata usually confined to areas between veins, rarely above veins, somewhat unevenly distributed, concentration about 53 per sq. mm., orientation irregular.

Stomata haplocheilic, monocyclic or possibly partly amphicyclic. Guard cells 8–11 μ wide × 32–45 μ long, exposed or more or less covered by subsidiary-cell papillae. Subsidiary cells 3–10, irregular, not forming a ring, polar subsidiary cells like laterals, size and shape of subsidiary cells similar to ordinary epidermal cells but often with a large hollow papilla on the side of the stomatal aperture, sometimes no well-marked papilla present but subsidiary cell margins thickened nearest the guard cells. Papillae pointing upwards or over stomatal aperture. Surface of subsidiary cells sometimes thicker than that of ordinary epidermal cells, showing parallel striations radiating outwards from the side of the stoma.

Lower epidermis of midrib showing rows of straight-walled, longitudinally elongated, polygonal cells, surface mottled, showing longitudinal striations, papillae sometimes present but not prominent, stomata rarely present. Upper epidermis of midrib unknown.

Lower cuticle of lamina thin (about 1 μ thick) walls of cells between veins obscure, usually appearing broken but sometimes showing sinuous waves. Cell walls below veins better marked, straight, thin. Cell surface mottled, occasionally showing a median papilla and striations. Lower cuticle otherwise as lower epidermis.

Holotype. Brit. Mus. (N.H.) Palaeont. Dept. no. V.34454.

Locality and horizon. Mhukuru Coalfield, Songea District, Tanganyika; Ecca Series ("Upper Coal Measures").

Description. A single specimen was found (Text-fig. 12, A). The leaf substance appears to have decayed considerably during preservation. It shows only the lower epidermis and the substance of the veins. The upper epidermis is preserved only at a few points (where it overlaps the lower and the intervening leaf substance). In places the veins appear sinuous but this is clearly due to displacement during preservation as the cells above veins run straight. There are two or possibly three anastomoses between lateral veins. Occasionally veins and midrib show scalariform tracheids with sides of varying width but usually about 14 μ wide and spiral tracheids about 10 μ wide. Some exposed guard cells show lateral lamellae of Gymnosperm type and thinner areas at the poles. A few two-winged pollen grains occur on the epidermis.

The species is named after Mr. D. A. Harkin of the Tanganyika Geological Survey who collected the material.

Comparison. *Rhabdotaenia harkini* differs from *R. danaeoides* in having a comparatively higher concentration of veins especially near the margin (*R. danaeoides* has 12–16 veins per cm. near the midrib, 15–20 near the margin; *R. harkini* has 15–18 near the midrib, 24–28 near the margin). In *R. harkini* about half the veins are forked and a number of these are forked twice; in *R. danaeoides* only about one-third of the veins are forked and twice-forked veins are very rare. The upper and lower epidermis of the two species are, as far as they are known, similar; the only differences are: (1) the larger and more prominent papillae present in most cells of the lower epidermis of *R. harkini* (in *R. danaeoides* the papillae are rather obscure and only occasionally seen), and (2) in *R. harkini*, while some stomata are fully

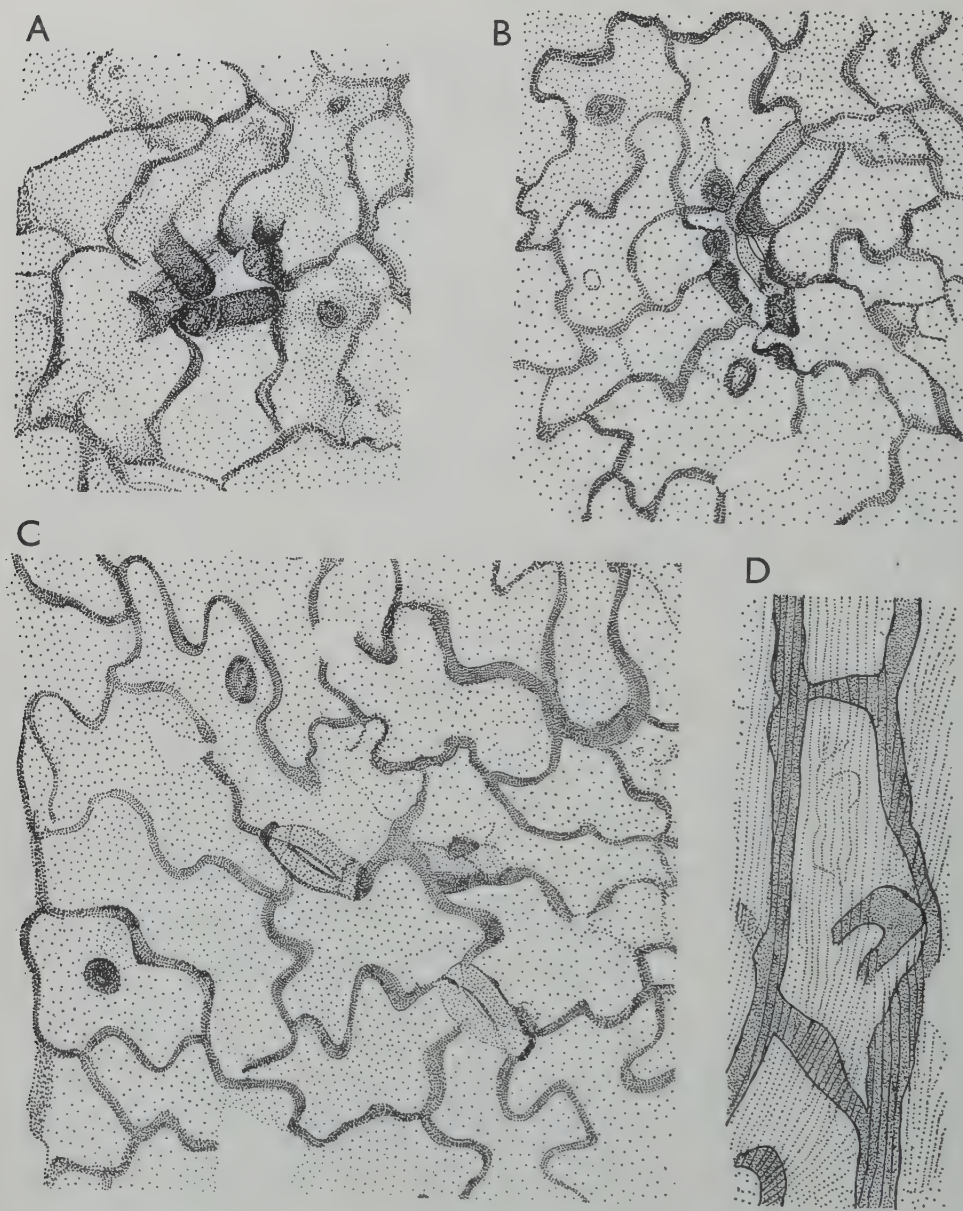

FIG. 14. *Rhabdotaenia harkini* n. sp. A, stoma from stomatiferous area near midrib protected by rather long papillae. × 400. B, part of Text-fig. 13, B showing details of a moderately protected, possibly partly amphicyclic stoma. × 400. C, another part of Text-fig. 13, B, showing details of two exposed stomata. × 400. D, a cell under vein from Text-fig. 13, D, showing parallel longitudinal striations and median papilla. × 800. All from the Holotype (V.34454).

exposed exactly like those of *R. danaeoides*, there are others which are more or less protected by epidermal papillae. No such protected stomata have yet been observed in *R. danaeoides*.

These supposed differences are, however, based on the comparison of a single specimen of *R. harkini* with three very incompletely preserved ones of *R. danaeoides*. Thus the range of variation of neither species is known and, though they may prove to be identical it seems advisable to distinguish them for the present.

Scale Leaves

(Pl. 20, figs. 3, 4; Text-fig. 15)

Locality and horizon. Mhukuru Coalfield, Songea District, Tanganyika; Ecca Series ("Upper Coal Measures").

Description. Twelve scale leaves of varied form were examined and also some fragments. Text-fig. 15, A shows a lanceolate scale overlying the cordate base of another scale. They are 1·7–2 cm. long and 0·7–1·2 cm. wide, rather convex with an ill-defined broad midrib and diverging veins which occasionally fork and anastomose.

Text-fig. 15, B shows a small rounded scale with a broad base and Text-fig. 15, C shows a group of somewhat larger rounded scales looking like a bud. The veins are more distinct. There is no definite midrib but merely a number of longitudinal strands. Again a few vein anastomoses were seen.

Both broad and lanceolate scales when isolated or transferred and seen in transmitted light show a scarious margin. Some of them show fibres in vein meshes. They usually have short simple hairs, about 300 μ long, on their outer side and at the margins, but some, e.g. the scale in Text-fig. 15, B, show none. The cuticles of the different forms are rather similar. The cuticle of the outer (convex) side is up to 2 μ thick. Its cells are polygonal with straight or arched sides. The cells above veins are narrower. Single-celled hair bases, occasionally with the cutinized hair still attached, are unevenly distributed between the ordinary epidermal cells (Text-fig. 15, D, E). Stomata are absent.

The cuticle of the inner (concave) side is more delicate with rather obscure cell outlines. No definite stomata could be recognized and no hair bases were observed.

Remarks. Similar scales have been described by Feistmantel (1880, 1882), Zeiller (1896, 1902), Seward (1897, 1904), Arber (1905, 1905*a*) Seward & Sahni (1920), Walkom (1921, 1922, 1928, 1931), Walton (1929) and others. Zeiller (1896, 1902) figured some specimens clearly showing anastomosing veins as in *Glossopteris*. Such scales have usually been attributed to *Glossopteris*, and sometimes to *Noeggerathiopsis*, but with little evidence beyond association. In the cores from Mhukuru they are found in association with leaves of *Glossopteris fibrosa* and *G. colpodes* (as well as seeds, sporangia and roots). No specimens of *Noeggerathiopsis* occur in the flora. The present specimens may be ordinary protective scales of the vegetative bud of *Glossopteris*. Their form is fully consistent with this and their cuticles resemble those of *G. fibrosa*. There is no reason at all to regard them as reproductive organs

and certain of these scales when transferred were proved to contain no sporangia, seeds or other bodies.

Sporangia

Similar bodies :

1905. " Sporangium-like organs of *Glossopteris browniana* ", Arber, p. 324, pl. 30, figs. 1–3 ; pl. 31, figs. 1–5.
1905*a*. " Fructification of *Glossopteris* ", Arber, p. 39, text-figs. 12–15.
1907. " Sporangia ", Seward, p. 68, pl. 8, figs. 7, 7*a*.
1919. " Sporangia ", Lundqvist, p. 12, pl. 1, figs. 8, 9.
1928. " Microsporangia of *Glossopteris* (Arber, 1905) ", Walkom, p. 561.

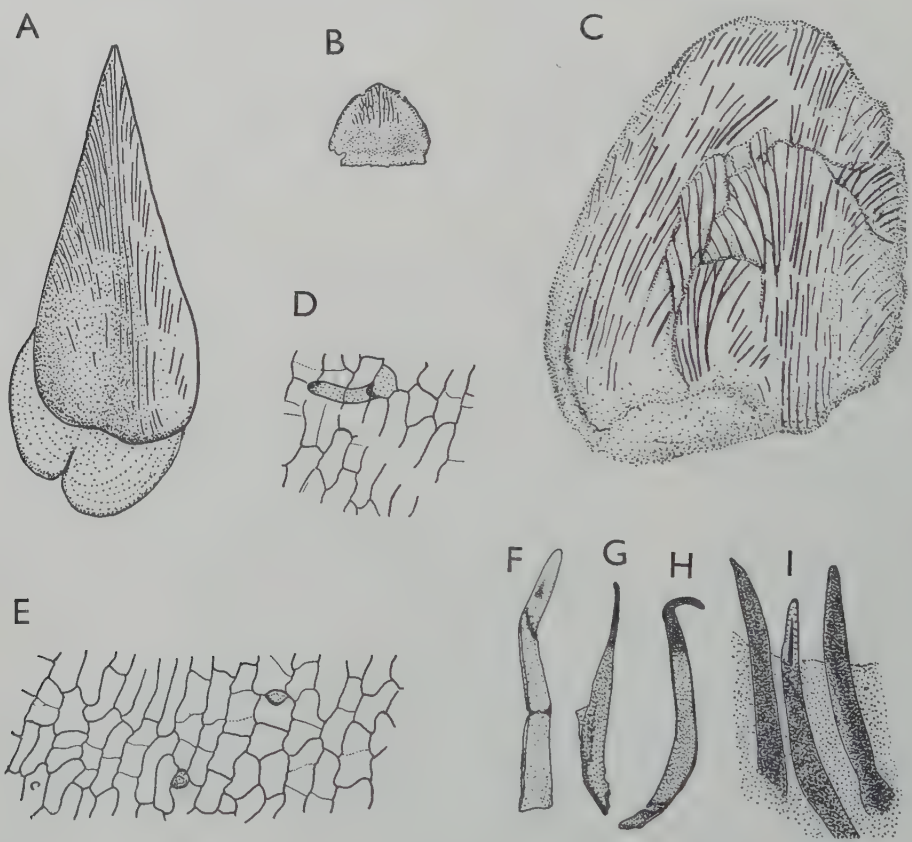

FIG. 15. Scale leaves. A, a lanceolate scale leaf and the cordate base of another. V.34468. B, rounded scale leaf with a broad base (see also Pl. 20 fig. 3). V.34453. C, group of rounded scale leaves resembling a bud. V.34468. D, cuticle of the outer (convex) side of a scale leaf with a cutinized hair and hair base. V.34468*a*. E, cuticle of the outer (convex) side of the same scale leaf showing two hair bases and epidermal cells. F, two-celled hair from a scale leaf. V.34468*b*. G, H, single-celled hairs from the same scale leaf. I, leaf epidermis with attached hairs. V.34468*b*. A–C, × 3 ; D–I, × 125.

1932. " Sporangia ", Du Toit, p. 384, pl. 40, figs. 9–12.
1955. " Male fructifications referable to *Glossopteris* ", Sen, p. 48, pls. 7, 8.
1956. " New type of fructification referable to *Glossopteris* ", Sen, p. 337, text-figs. 1–3.

Specimens from Mhukuru

(Pl. 21, figs. 1–6 ; Text-figs. 16, 17, A–D)

Seventeen specimens, from Mhukuru Coalfield, Tanganyika, show a large number of sporangia either isolated or occurring in groups. The best specimens were, however, obtained by dissolving pieces of rock in HF. These show slender axes, up to 200 μ thick, branching freely. Each ultimate branch ends in a single sporangium. A longitudinal strand, at some points showing scalariform tracheids about 8 μ wide, is present throughout the axes. Their surface cells are elongated but at a few points in the thicker axes they are short.

Laterally compressed sporangia are oval with one side nearly straight, the other strongly curved (Text-figs. 16, A, E, F, 17, C). They are up to 3 mm. × 1·25 mm. but many are much shorter, some because they were compressed longitudinally (Text-fig. 16, B) but others must have been smaller originally.

Most of the sporangia have dehisced along the whole length of their convex side but the line of dehiscence is often oblique. Two flaps of the wall of such sporangia are either compressed almost flat or contain rock matrix and stray spores. A few sporangia are still closed and full of spores (Pl. 21, figs. 5, 6). These enclosed spores are oval and two-winged, 40–55 μ long and 25–30 μ wide (Text-fig. 17, D). One sporangium, however, which must be another species, contained winged spores measuring about 70 μ by 50 μ. In other respects this sporangium is similar to those with smaller spores.

The wall of the sporangium consists of an outer layer of elongated fibrous cells running lengthwise (parallel with the slit). The wall cells are 150–400 μ long and 6–35 μ wide tending to be narrower towards the apex and base. The surface of the wall cells is thick and uniformly dark ; a few show irregular paler areas probably due to poor preservation. The sides of the cells are straight or slightly sinuous (Text-figs. 16, G, H). The lines where these cells join are often represented by narrow and occasionally by wide gaps (the cuticle, however, is without any corresponding gaps). The outer surface of the sporangial wall cells projects and their walls are sunken. The inner surface of the wall is almost smooth. No specialized cells were recognized along the suture. At the apex of the sporangium the wall cells radiate from a point which is sometimes slightly projecting and marks the apical end of the slit. No specialized cells like an annulus occur anywhere.

At the base of the sporangium the narrowing fibrous cells of the wall converge and enter the stalk which is up to 1 mm. long × 0·1 mm. thick. It is often attached asymmetrically to the straight side of the sporangium (Text-figs. 16, A, E, F, 17, C). The body of some sporangia is bent almost at right angles to the stalk (Text-fig. 16, E, F).

On maceration the sporangium yields two cuticular coats, an outer smooth coat showing the outlines of the fibrous cells and an inner granular membrane showing

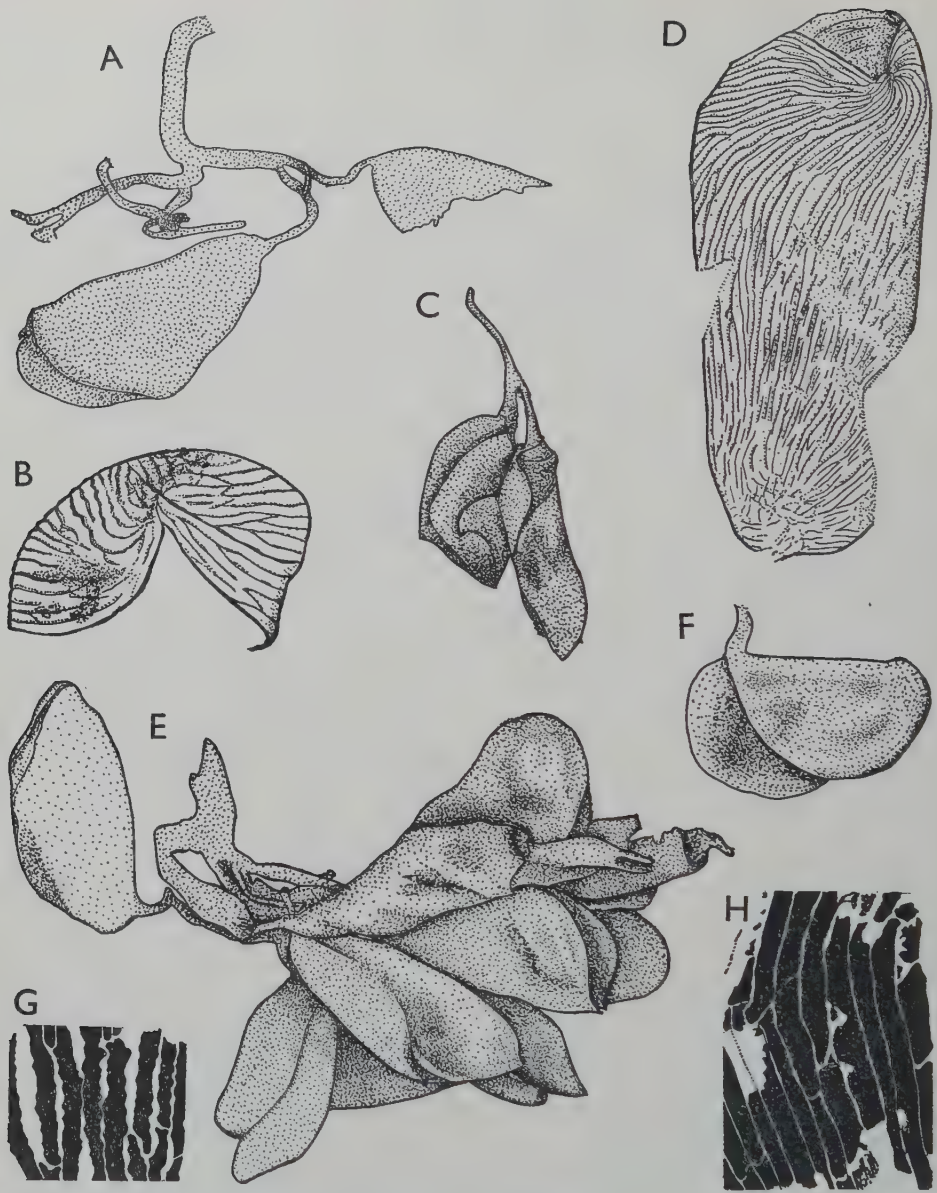

FIG. 16. Sporangia from Mhukuru Coalfield, Tanganyika. A, branching stalks terminating in sporangia; some sporangia have broken off. V.34457. × 25. B, transversely flattened sporangium. V.34469. × 50. C, forked axis bearing terminal sporangia. V.34457. × 25. D, sporangium showing wall-cells radiating from a point at the apex. V.34469. × 50. E, group of sporangia attached to a branching axis (see also Pl. 21, fig. 2). V.34457. × 25. F, sporangium, side view, bent almost at right angles to the stalk. V.34470. × 25. G, sporangium wall showing dark cell-interior from sporangium in Pl. 21, fig. 3. V.34458. × 125. H, wall cells of a sporangium. V.34471. × 125.

straight or slightly sinuous-walled, isodiametric polygonal cell outlines typically about 40 μ across. The cells of the outer membrane, particularly those near the sporangial stalk, may show a median rounded mark (papilla). Some of the dehisced sporangia show spores in great variety which had evidently got in before preservation.

The sporangia occur in association with leaves of *G. fibrosa* and *G. colpodes* (as well as scale leaves, *Spermatites crystallinus*, *S. tetrapterus*, *Vertebraria*, and some thin roots).

Specimens from Australia

(Pl. 21, fig. 7 ; Text-fig. 17, E, F)

A few sporangia from Newcastle, New South Wales, have been examined and the following notes throw additional light on the African material.

1. *Detached sporangia.* Fourteen specimens from Newcastle (additional to those described by Arber, 1905, 1905*a*) agree very closely with the African ones. None of them is, however, as large as the largest African sporangia. They measure 1–2·5 mm. × 0·6–1·3 mm. A few of them show stalks about 100 μ thick. The wall shows very similar cells to the African ones (projecting outwards but smooth inside) and cuticles were obtained corresponding to the African ones. All have dehisced but a few retain numerous spores, all of one type (Text-fig. 17, F).

The sporangia figured by Arber (1905, 1905*a*) are much like these specimens (Text-fig. 17, E) except that those described by Arber have suffered complete oxidation and no cuticle or other organic matter remains.

2. *Attached sporangia.* Two specimens are available. One (V.24233) is a slightly concave disc (Pl. 21, fig. 7) thickly covered with sporangia compressed in various planes. No stalks were seen and it is not known how the sporangia were attached. The sporangia are empty. A little carbon of the wall remains but the wall cells are replaced by delicate rods of a mineral. The margins of the disc show small epidermal cells arranged in parallel rows. The rows are not concentric but meet the margin at a small angle. The surface of the disc where it is not covered with sporangia is wrinkled.

The other specimen, V.24244, is a fragment of what appears to be a similar disc. Its sporangia are full of spores but they proved ill-preserved. They are represented by rounded outlines about 14 μ wide and they are probably two-winged. This specimen was transferred and the back of it proved to be smooth ; its surface shows small epidermal cells arranged in parallel rows, running from what is regarded as the base to the apex, i.e. longitudinally.

Discussion. The Newcastle specimens were finally proved to be sporangia by the discovery of a specimen (V.24244) with sporangia still full of spores. They look very much like the African ones, which also have been proved to be sporangia.

Arber (1905, 1905*a*) who first noticed them believed them to be sporangia ; Seward (1907) and Lundqvist (1919) agreed. Thomas, H. H. & Mrs. (1925) and Walkom (1928) thought that they might be ramenta. The presence of spores adhering to empty specimens as noted by du Toit (1932) is not enough to prove them to be sporangia, but the occurrence of nearly ripe specimens full of spores, such as those

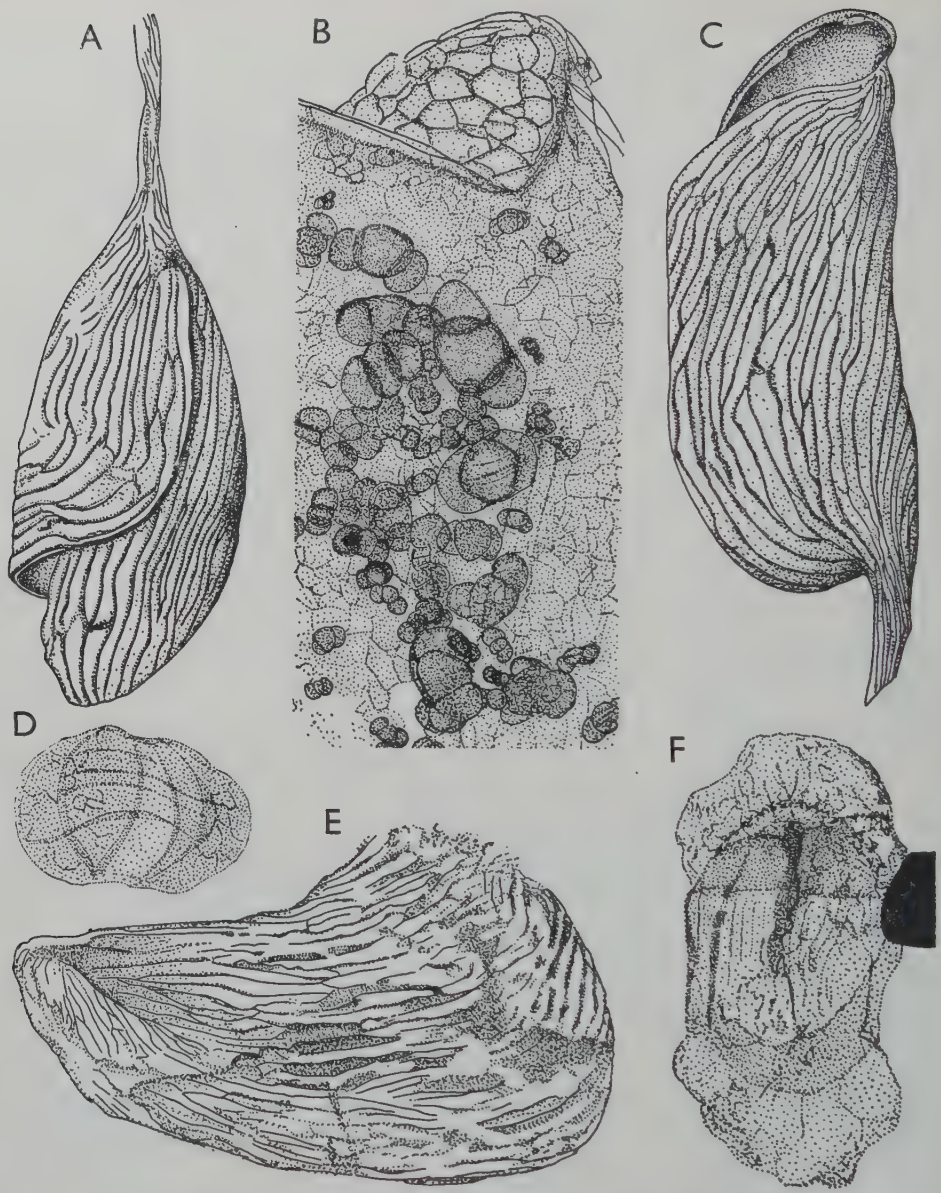

FIG. 17. Sporangia and spores. A, longitudinally dehisced sporangium. V.34457. × 50. B, two-winged spores of diverse sizes adhering to the inner cuticle of a dehisced sporangium (see also Pl. 21, fig. 1). V.34456. × 125. C, dehisced sporangium in side view. The stalk is attached on the flat side. V.34457. × 50. D, two-winged spore from an undehisced sporangium. V.34472. × 800. E, carbonized sporangium as seen in a transfer preparation. V.34491*a*. × 50. F, typical two-winged spore from a dehisced sporangium in a pull. The black spot is part of a wall cell. V.24245*a*. × 800. A–D from Mhukuru Coalfield, Tanganyika. E, F from Newcastle, New South Wales.

in specimen V.24244 and the undehisced African specimens, make their identity certain.

Sen (1955) described a few similar sacs but apparently with transverse dehiscence, which suggests that they are different from the specimens described here. In 1956 he described others with longitudinal dehiscence which are even more similar.

Arber (1905 : 41, 1905*a* : 325) described and figured a specimen, V.7202, in which he believed that these sporangia were borne on a scale (perhaps like one of the scales here regarded as bud scales). There is little of this scale preserved, however. Re-examination of the specimen merely shows that some of the sporangia lie beneath the scale fragment while others are clear. There is no evidence at all of attachment.

No organ exactly like the disc has been described. Several incompletely known fossils may, however, prove similar. These include *Eretmonia natalensis* du Toit (1932, pl. 40, figs. 9–12), *Conites* Seward (1897) and Seward and Leslie (1908) and the scale, " *Glossopteris* sp." (White, 1908, pl. 7, figs. 5, 5*a*, 6), which shows small rounded bodies on its surface. *Ottokaria ovalis* White (1908, pl. 7, figs. 7, 7*a*) and *Ottokaria leslii* Thomas (1921 : 285, text-figs. 1, 2) may be similar.

Ottokaria bengalensis Zeiller (1902) and Seward & Sahni (1920), *Lanceolatus* and *Scutum* Plumstead (1952, 1956) are assumed to be of a different nature. The rather regular arrangement of rounded bodies in *Scutum* is apparently different from the irregular arrangement of sporangia seen in the discs described here. I can see no similarity between the much larger " male bracts " of that organ and the present sporangia.

These Australian sporangia are of particular interest in relation to the African ones because while they look so similar they are probably borne in rather different ways. Not a single African specimen, in the present collection, shows a disc-like structure and it cannot be assumed that the Australian and African sporangia belong to closely related plants. Both of course occur in *Glossopteris* floras in association with various species of *Glossopteris*. It is possible that they belong to the same plants as the associated leaves but so many varied organs have been assigned to *Glossopteris*, on grounds of association, that I refrain from assigning these sporangia to it.

Genus ***SPERMATITES*** Miner

This non-committal designation is used because the structure of this seed though characteristic is not adequately understood. I feel sure that when it is so understood it will be well worthy of generic rank.

Spermatites crystallinus n. sp.

(Pl. 20, fig. 6 ; Text-figs. 18, 19)

Diagnosis. Seed, flattened, orthotropous, 1·25–1·5 mm. long, 1–1·1 mm. wide and 0·75 mm. thick, oval, micropylar end obtusely pointed, chalazal end rounded, margins often bearing fragments of tissue (wing or possibly fruit substance ?). Surface of seed often showing longitudinal rows of polygonal cells about 30 μ wide. Cuticles : nucellus thickly cutinized showing elongated cells 30–75 μ long and 20–40

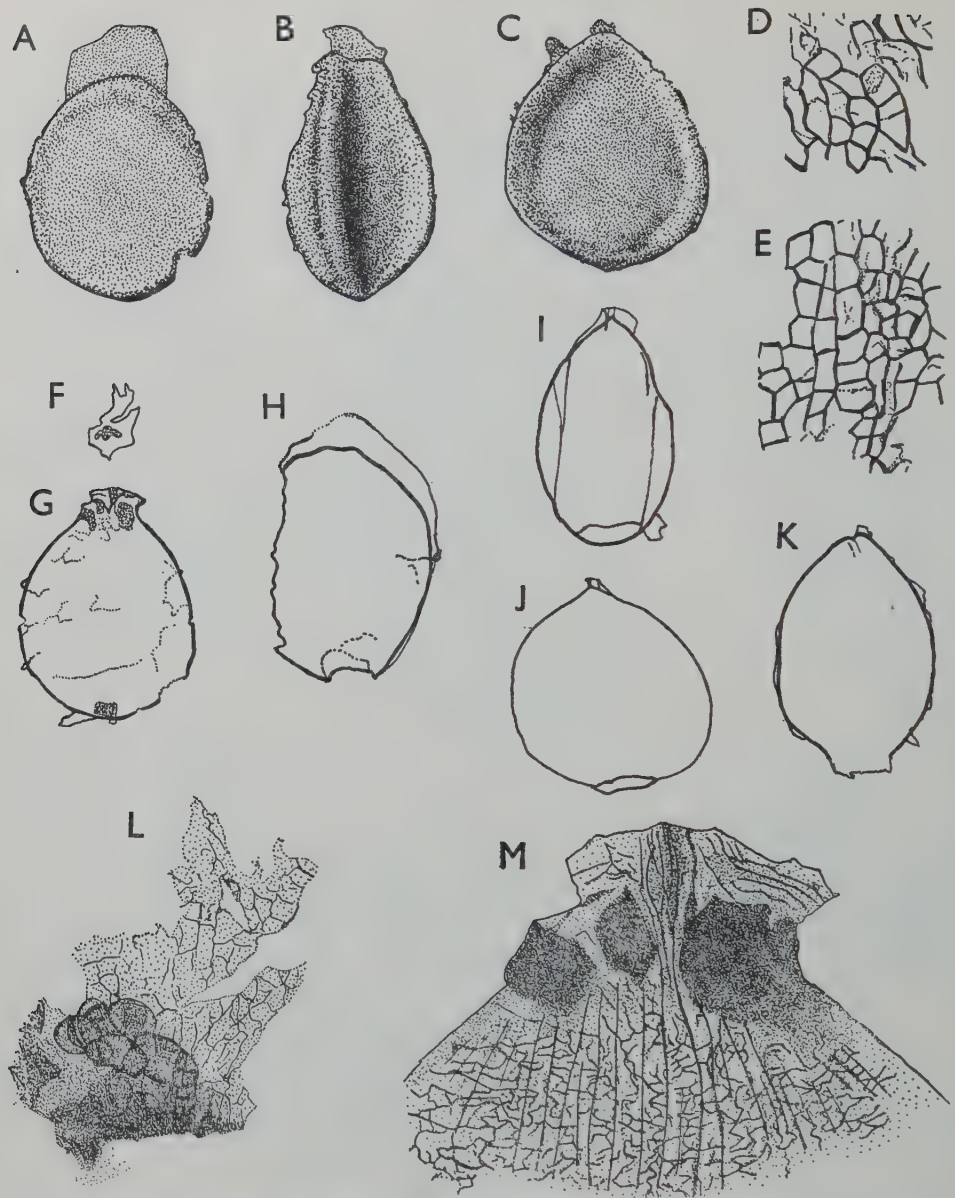

FIG. 18. *Spermatites crystallinus* n. sp. A–C, compressed seeds showing plates of tissue at the margin. B, shows a narrower seed with a longitudinal ridge on the surface. A, Holotype, V.34473. B, V.34474. C, V.34475. D, surface cells of marginal plate of tissue as seen before maceration of seed in A. E, surface cells of seed in A before maceration. F, cuticle of plate of tissue at margin of seed in A (broken while mounting). G, nucellus of seed in A with portions of outer membranes. H, cuticle of seed immediately outside the nucellus (inner cuticle of integument). V.34476. I, J, cuticles of seeds showing micropylar canals and chalaza. V.34477–78. K, cuticle of seed. V.34479. L, cuticle in F more magnified ; a few two-winged pollen grains are sticking to it. M, top part of G, more magnified, showing micropylar canal. The three dark masses are unmacerated carbon. A–C, F–K × 25. D, E, L, M × 125.

μ wide, walls thick towards micropylar end, thinner elsewhere, straight or slightly wavy. Micropylar canal 80–90 μ long, chalaza about 300 μ wide. Megaspore membrane absent but nucellus enclosing a dark-coloured tissue often showing polygonal cells typically 15 μ long $\times$ 45 μ wide, walls up to 2 μ thick, usually appearing hyaline. Outer cuticles delicate ; immediately outside nucellus a delicate membrane (? inner lining of integument) showing narrow elongated cells which become sinuous near micropyle, cells typically 70 μ long $\times$ 15 μ wide.

Stone of integument not very thick, composed of elongated fibres. Outer cuticle (possibly surface of integument) showing short polygonal cells about 30 μ wide, cell surface often showing a rhomboidal, hexagonal or octahedral mark like the imprint of a crystal.

Holotype. Brit. Mus. (N.H.) Palaeont. Dept. no. V.34473.

Locality and horizon. Mhukuru Coalfield, Songea District, Tanganyika ; Ecca Series (" Upper Coal Measures ").

Description. Thirty-three of these seeds were isolated by dissolving pieces of rock in HF. Most of them are rounded but a few are narrow and show a longitudinal ridge on either surface (Text-fig. 18, B). On maceration their nucellus shows folds corresponding to the surface ridges. I believe these are laterally compressed seeds, they are about 0·75 mm. thick which is perhaps the original thickness of the seed.

Several seeds carry irregular plates of tissue at the margin and these may occur at any point (Text-figs. 18, A–C). The irregular margins of these plates may be original or may have been caused by breakage before preservation or during extraction. This tissue yields a delicate cuticle showing polygonal cells about 30 μ wide. It might represent some sort of wing or may possibly be a relic of the tissue of a fructification.

Maceration always yields the nucellus cuticle and usually fragments of other cuticles around it. Their nature is, however, not as clear as that of the nucellus. The inner cuticle of integument is best seen towards the micropyle. A few seeds yielded internal casts of fibres in the form of rods covered with short outgrowths which must have originally occupied pits. One seed yielded fragments of cuticle showing elongated tracheid-like cells with scalariform marks (Text-fig. 19, I) probably representing impressions of tracheids (cf. Harris, 1941 ; 88, text-fig. 5, F.). The nature of the outer cuticle showing crystalline imprints is not clear and could not be proved to be the same as the cells seen on the outside of the seed though it may be so.

Seven out of twelve seeds showing suitable micropylar ends have pollen grains on the surface of the nucellus around its micropylar end. In two seeds they also occur farther away from the micropyle. They are underneath the delicate inner cuticle of the integument and as far as can be seen most of them are of the same type. Those seen clearly are two-winged, about 30 μ $\times$ 50 μ in size (Text-fig. 19, G) but many are so crushed that their shape is obscured ; their texture is, however, similar to the clearer ones. Two exceptional round pollen grains about 60 μ in diameter were also noticed (Text-fig. 19, E). The presence of these numerous pollen grains suggests that they are not accidental but are the result of the normal pollination processes. The grains look just like those of the microsporangia and they provide

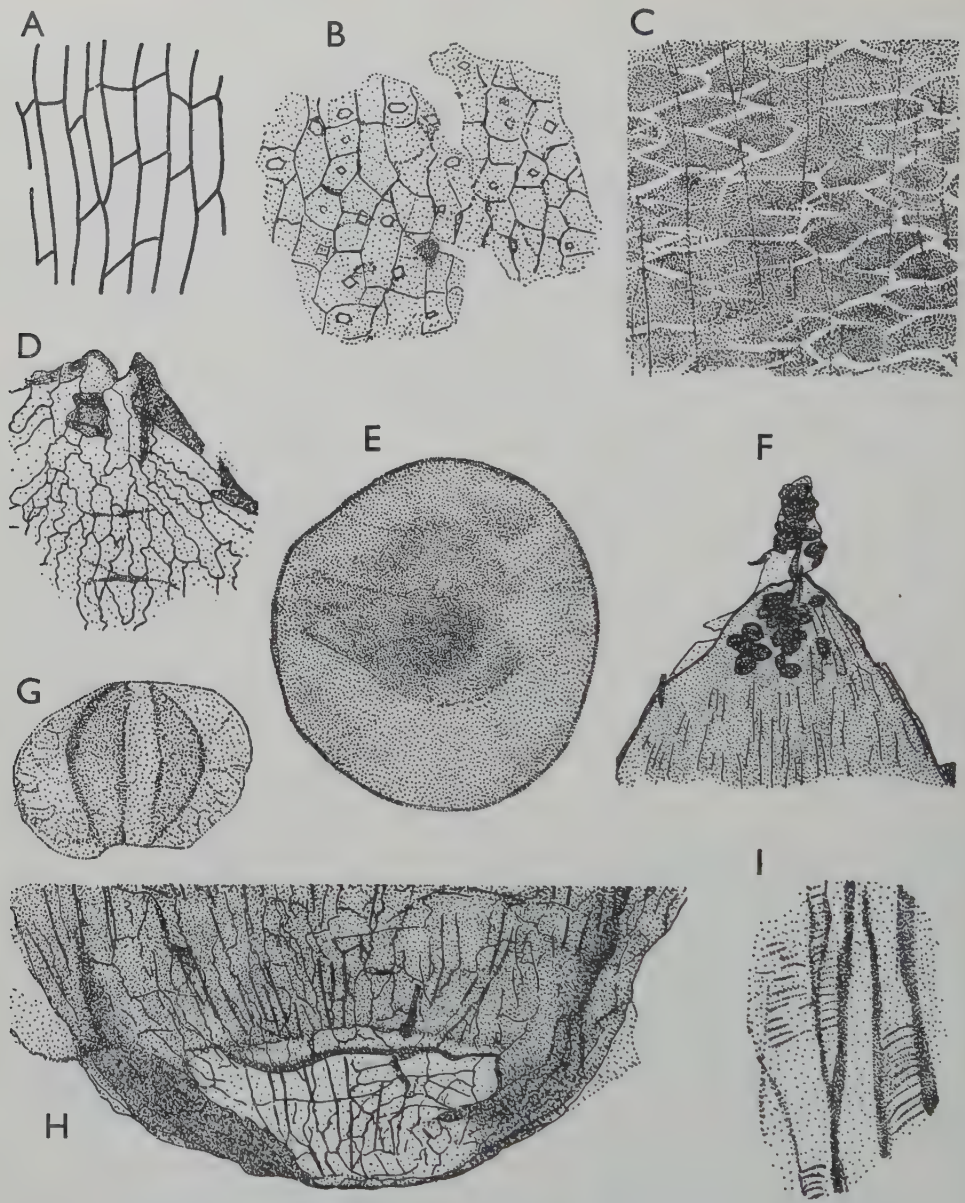

FIG. 19. *Spermatites crystallinus* n. sp. A, nucellar cuticle showing elongated cells. V.34480. × 200. B, outer cuticle of seed showing polygonal cells and crystalline imprints. V.34481*a*. × 200. C. dark tissue inside nucellus showing hyaline cell walls. V.34482. × 200. D, portion of cuticle immediately outside nucellus in Text-fig. 18, H, from near micropylar end of seed showing sinuous-walled elongated cells and a pollen grain. V.34476. × 200. E, unusual rounded pollen grain from the nucellus of a seed. V.34475. × 800. F, part of nucellus of seed showing numerous pollen grains at the micropylar end. A number of pollen grains are also seen sticking to the plate of tissue outside the micropyle. V.34483. × 50. G, pollen grain from the nucellus of a seed showing two wings and a body. V.34483. × 800. H, Chalazal hole of seed shown in Text-fig. 18, I. × 125. I, membrane showing scalariform imprints. V.34479. × 400.

evidence that these seeds and microsporangia probably belong to the same plant species. It is noteworthy that the micropylar canal is shrivelled and narrower than the diameter of a pollen grain. It must have been wider when it admitted them. Clearly the pollination is essentially gymnospermous. Similar pollen is found also on the surface of the seed where, however, it is not significant.

Comparison. The most similar seed of the *Glossopteris* flora is *Spermatites indicus* Srivastava (1954). It differs, however, in having surface cells twice as wide as those in *S. crystallinus*. Certain inner cuticles are present in *S. indicus* which may correspond to those of *S. crystallinus* but their nature is very obscure. There is nothing to suggest that *S. indicus* has any sort of marginal tissue.

Rather similar orthotropous seeds are known in the Mesozoic genus *Caytonia* (Harris, 1940 : 724) where, however, no marginal flange exists, and in the isolated seeds described by Harris (1932 : 14) under the name *Amphorispermum*.

Spermatites tetrapterus n. sp.

(Text-figs. 20, 21)

Diagnosis. Seed, flattened, orthotropous, 3–4·5 mm. long and 2–2·5 mm. wide, oval, micropylar end obtusely pointed, chalazal end rounded. Seed showing two strong ridges on the surface, representing compressed wings, other specimens without surface ridges. Surface showing rows of longitudinally elongated cells about 150 μ long and 25 μ wide. Cuticles : Nucellus moderately thickly cutinized showing elongated cells with straight or nearly straight walls, apical region or nucellar cap sharply distinguished by thick-walled cells with straight or nearly straight walls, up to 2 μ thick, lower part with thinner-walled cells, boundary region between nucellar cap and lower part normally showing scattered round thickenings 6–12 μ across. Micropylar canal very delicately cutinized, about 200 μ long $\times$ 100 μ wide, usually collapsed (chalaza not seen).

Megaspore membrane not present, nucellus often enclosing dark matter sometimes showing transversely elongated cell outlines. This tissue extends only as far as the base of the nucellar cap.

Inner cuticle of integument delicate showing obscurely marked longitudinally elongated cells.

Stone of integument not very thick, containing elongated fibres.

Outer cuticle of integument about 1 μ thick, showing cells which are usually elongated and narrow. Typical dimensions 150 μ $\times$ 25 μ but sometimes short and broad.

Holotype. Brit. Mus. (N.H.) Palaeont. Dept. no. V.34490.

Locality and horizon. Mhukuru Coalfield, Songea District, Tanganyika ; Ecca Series (" Upper Coal Measures ").

Description. Twenty-seven seeds were seen, seventeen of which were obtained by disssolving pieces of rock in HF. Some seeds are filled with rock matrix. If the ridges in the seed represent wings, they may be four-winged. The nucellus of seeds with surface ridges shows deep folds corresponding with the ridges, indicating that the nucellus of the seed was itself angular. In some seeds the cells of the nucellar

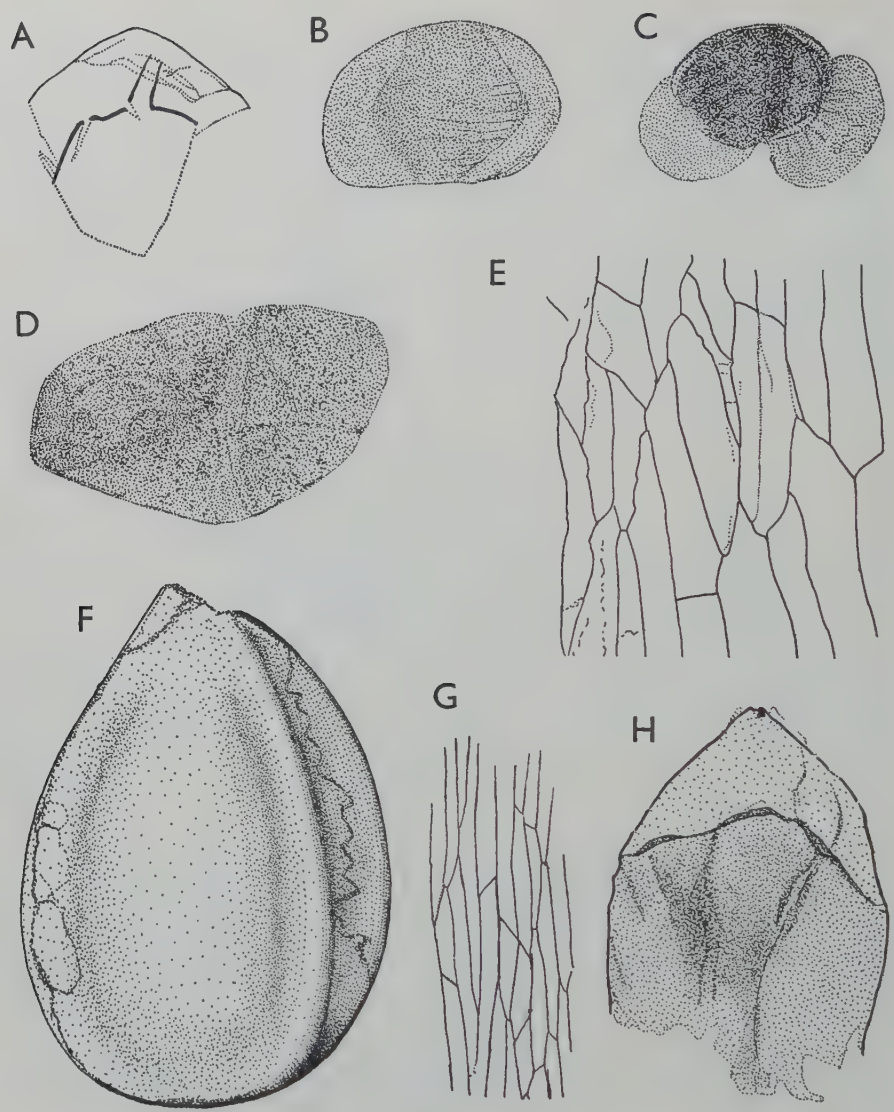

FIG. 20. *Spermatites tetrapterus* n. sp. A, upper part of macerated seed showing nucellus, micropylar canal and outer membrane. V.34484. × 25. B and C, two pollen grains (from inside the nucellus) showing two wings and a striped body. V.34485. × 800. D, unusual pollen grain from inside the nucellus of a seed. V.34486. × 800. E, outer membrane of seed showing straight-walled elongated cells. V.34487. × 200. F, compressed seed showing a ridge on the upper surface. Its interior is filled with rock matrix. Holotype, V.34490. × 25. G, surface cells of seed in F. × 125. H, nucellar cuticle of a seed. The black spot at the top represents pollen grains, a darker tissue is seen below the nucellar cap. V.34486. × 25.

cap form processes (Text-fig. 21, A–C). Text-fig. 21, A shows the top view of a nucellar cap in a seed which is probably obliquely compressed.

Seven out of ten seeds with suitable micropylar ends show numerous oval pollen grains inside the top end of the nucellus. In one seed (Slide V.34494) a mass of pollen grains is also seen inside the micropylar canal. Most of the measureable pollen

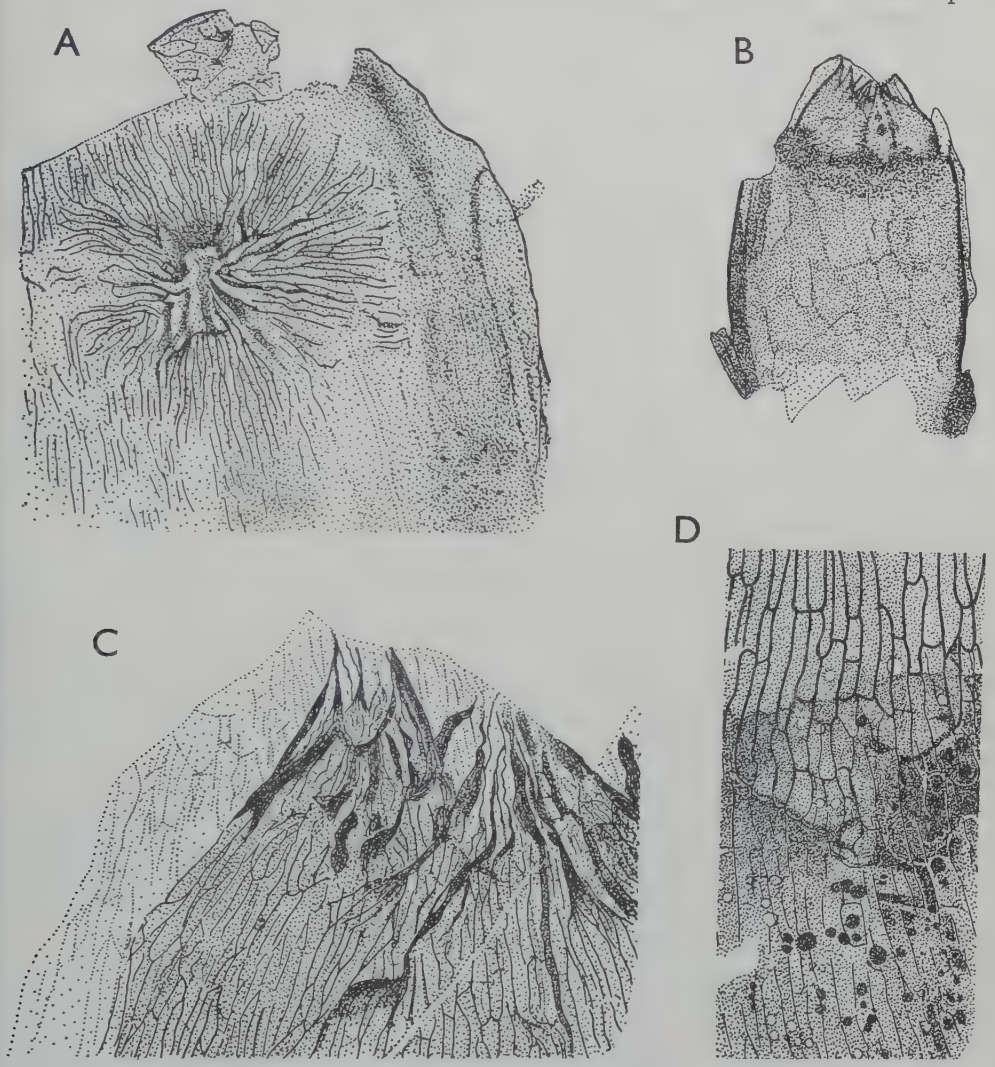

FIG 21. *Spermatites tetrapterus* n. sp. A, nucellar cap in top view showing radiating cell rows. V.34488. × 50. B, nucellus and inner cuticle of integument showing nucellar cap in side view. V.34489. × 25. C, upper part of B. There is a delicate cuticle outside the nucellus (inner lining of integument) and the apex of the nucellus forms processes. V.34489. × 125. D, part of B. The cells above belong to the nucellar cap and the dark spots occur at its junction with lower part of the nucellus. × 200.

grains are about 50 μ × 30 μ. They are two-winged and show a body with transverse striations. One pollen grain which has a similar texture and shows no wings is 60 μ × 40 μ, another is a smaller two-winged one measuring 35 μ × 25 μ.

Comparison. Similar seeds have been described from Wankie, Rhodesia, by Walton (1929 : II, pl. C, figs. 25, 26) but their fine details are unknown. These seeds show wing-like expansions which Walton regarded as formed by the angular inner tissue.

S. tetrapterus resembles *S. crystallinus* in its general organization but differs in being larger and in having surface ridges, *S. crystallinus* shows ridges only when laterally flattened and has a marginal tissue which is not present in *S. tetrapterus*. It has short surface cells while *S. tetrapterus* usually shows longitudinally elongated cells on the surface. *S. crystallinus* has an outer membrane showing short cells with crystalline imprints whereas the outer cuticle of *S. tetrapterus* usually shows elongated cells and no crystals.

III. SUMMARY

The paper describes details of the epidermal and cuticular structure of three new species of *Glossopteris* (*G. fibrosa*, *G. hispida*, *G. colpodes*) and a possible fourth (*Glossopteris* sp. A) from borehole cores in the Mhukuru Coalfield, Songea District Tanganyika. All the *Glossopteris* leaves, described here, agree in their haplocheilic stomata and in their guard cells having lignine lamellae of the Gymnosperm type. They range from mono- to amphicyclic but all have subsidiary cell papillae covering the stoma, palisade and spongy mesophyll cells and scalariform tracheids in veins. Fibres in vein meshes are found in *G. fibrosa* and *G. hispida*. *G. colpodes* is a wider-meshed form usually showing sinuous-walled epidermal cells on both the upper and the lower sides of the leaf. *G. hispida* is unique in having multicellular hairs on the lower surface of the leaf. The imperfectly known *Glossopteris* sp. A is rather like *G. fibrosa* but has no fibres in vein meshes. The species are compared with others of *Glossopteris* described by earlier authors.

A new genus *Rhabdotaenia* is made for the Indian leaf *Taeniopteris danaeoides* (Royle) and its fine structure is described. A rather similar leaf, *R. harkini*, is described from Mhukuru, Tanganyika. *Rhabdotaenia* shows haplocheilic stomata and differs from other taeniopterid haplocheilic leaves, e.g. *Doratophyllum* and *Bjuvea* (Florin, 1933) in having irregular subsidiary cells and rather exposed stomata with or without protecting subsidiary cell papillae.

Some rounded or lanceolate scale-leaves showing a scarious margin, an ill-defined midrib and anastomosing veins have been studied. They usually have short simple hairs on their convex side and occasionally fibres in vein meshes. The epidermal structure of the various forms is similar and resembles that of *G. fibrosa* of which they may be bud scales.

Fine details of some well-preserved African and Australian microsporangia, closely resembling Arber's " sporangium-like organs of *Glossopteris browniana* " are described. Some undehisced specimens were found to be full of two-winged spores. It was found that the African sporangia are borne terminally on branched

slender axes. Two discs bearing similar sporangia, from Newcastle, New South Wales, are also described ; one of them has sporangia full of spores. The finding of undehisced specimens, still full of spores, finally proves these bodies to be sporangia.

Two types of compressed seeds, *Spermatites crystallinus* and *S. tetrapterus* were found in the cores. Their structure is described in detail. Both show gymnospermous pollination by two-winged spores. Both the sporangia and the seeds may belong to the same plants as the *Glossopteris* leaves abundant in this collection. Similar sporangia and seeds occur in *Glossopteris* bearing rocks at Ranigenj coalfield.

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PLATE 18

Glossopteris fibrosa n. sp.

FIG. 1. Epidermal pull showing a rather exposed stoma with lignine lamellae. V.34440*d*. × 400.

FIG. 2. Lower epidermis isolated with HF. The dark lignine lamellae of stomata are obvious. There are two folds both exposing the inner side so that the stomatal pits appear raised. V.34441. × 100.

FIG. 3. Upper epidermis showing pale cell walls and dark cell contents with granules of various sizes. V.34442. ×450.

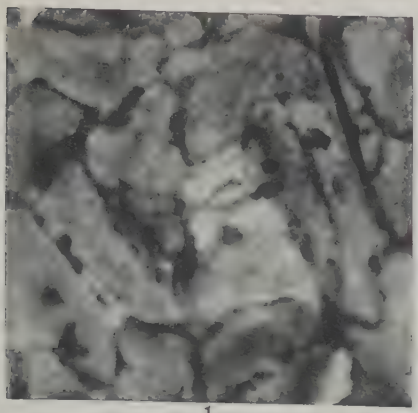
FIG. 4. Cuticle showing stoma. The polar and lateral lignine lamellae have dissolved by maceration. V.34443. ×400.

FIG. 5. Tracheids from the midrib. V.34440*d*. × 450.

Glossopteris hispida n. sp.

FIG. 6. Matrix in contact with the lower surface of leaf showing hairs when moistened with oil. Holotype V.34450. × 10.

FIG. 7. Pull showing lower epidermis and a fibre between two veins. A few spongy mesophyll cells (dark rectangles) remain. V.34450*a*. × 110.



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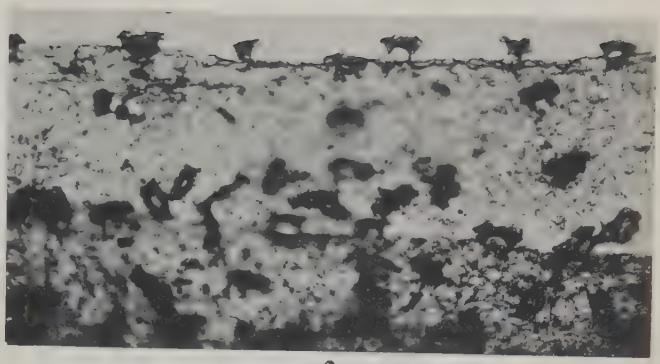

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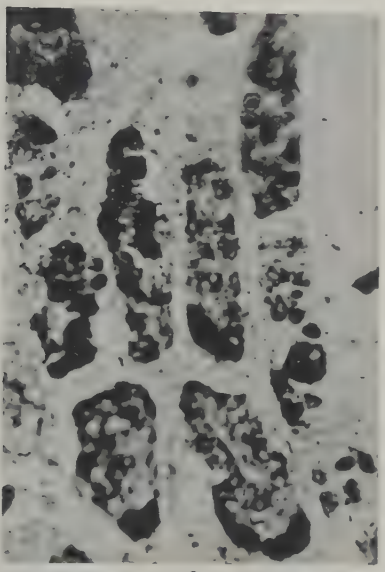

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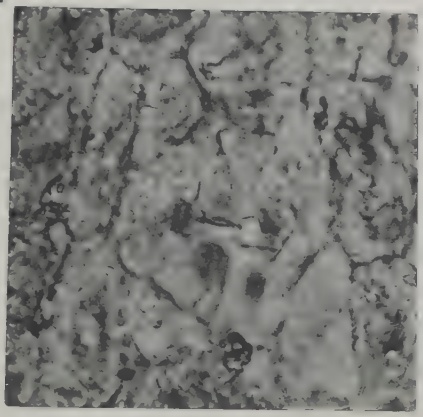

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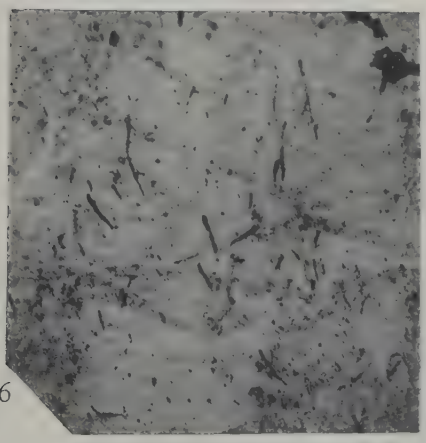

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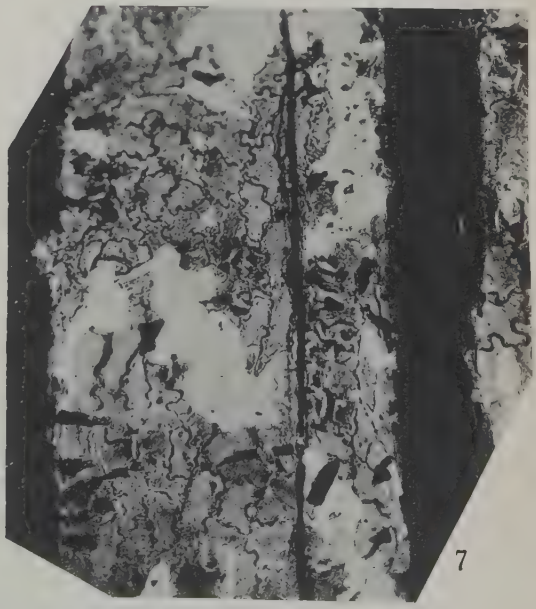


7

GLOSSOPTERIS FIBROSA, G. HISPIDA

PLATE 19

Glossopteris fibrosa n. sp.

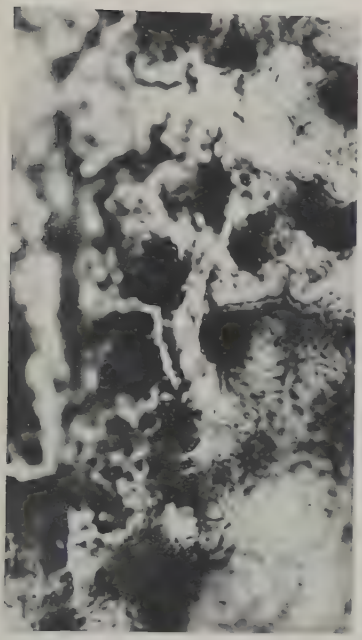
FIG. 1. Epidermal pull showing stomatal aperture protected by thickened subsidiary cell papillae. V.34449*a*. × 800.

Glossopteris colpodes n. sp.

FIG. 2. Epidermal pull showing stoma protected by thickened subsidiary cell papillae. V.34466*a*. × 800.

Glossopteris hispida n. sp.

FIG. 3. Epidermal pull showing stoma protected by subsidiary cell papillae. V.34450*a*. × 800.



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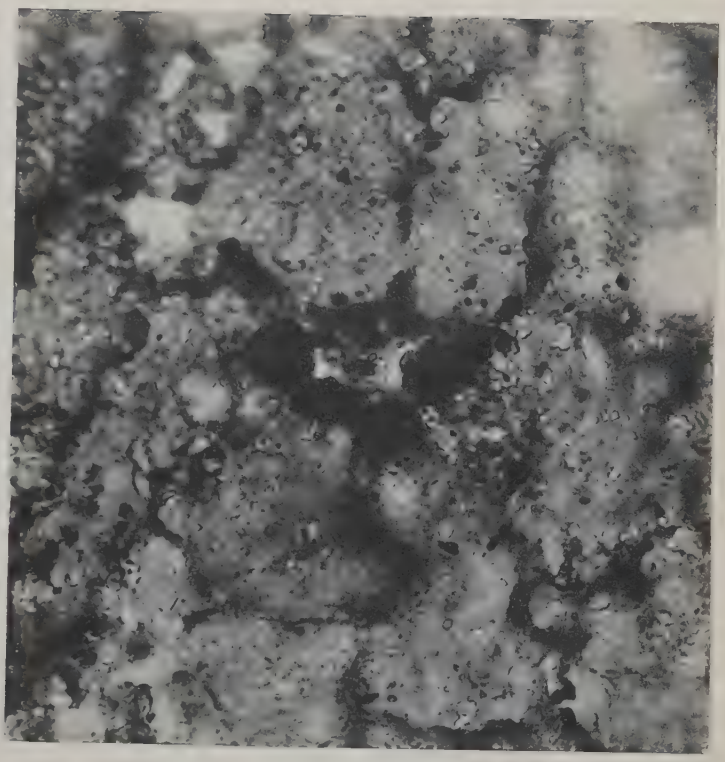

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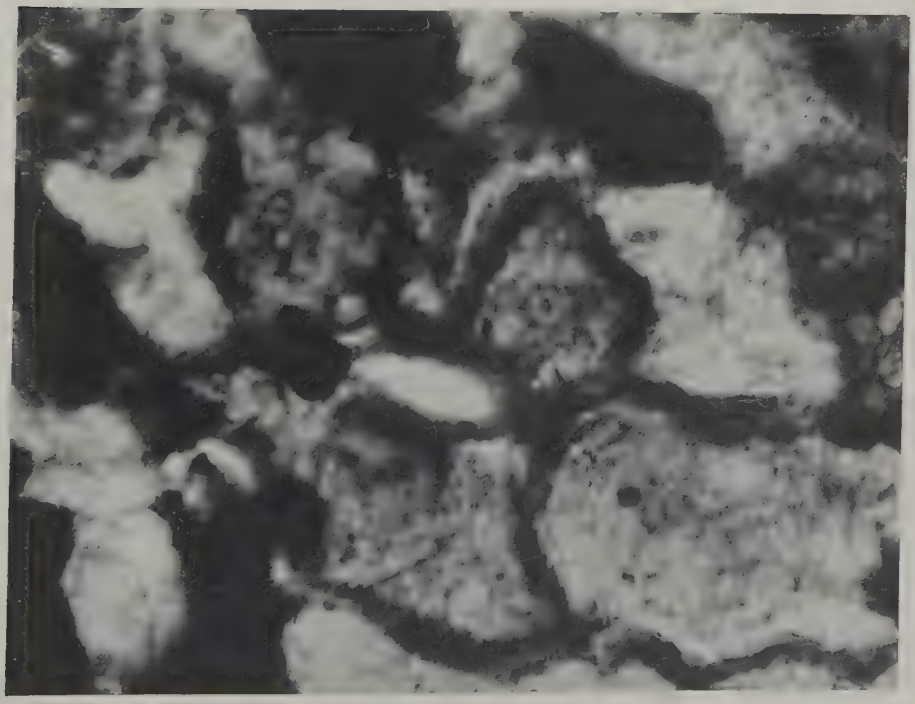


3

GLOSSOPTERIS FIBROSA, G. COLPODES, G. HISPIDA

PLATE 20

Glossopteris hispida n. sp.

FIG. 1. Pull showing a one-celled hair base overlapping a number of epidermal cells. V.34450*a*. × 450.

FIG. 2. Pull showing a two-celled hair base overlapping epidermal cells. V.34450*a*. × 450.

Scale Leaves

FIG. 3. Scale leaf isolated from rock with HF. V.34453 (1). × 6.

FIG. 4. Scale leaf isolated from rock with HF. V.34453 (2). × 6.

Rhabdotaenia harkini n. sp.

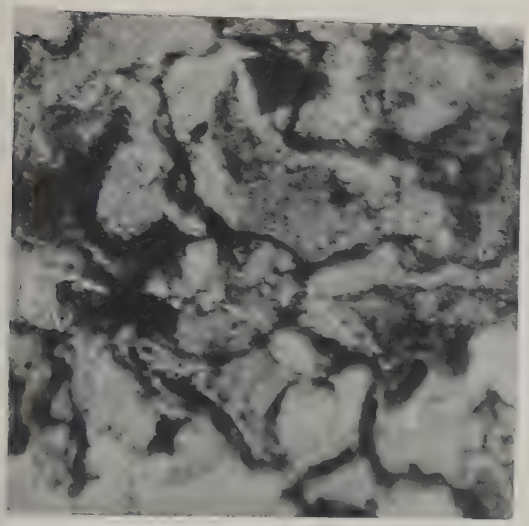
FIG. 5. Stoma protected by papillae of irregular subsidiary cells. V.34454*b*. × 400.

Spermatites crystallinus n. sp.

FIG. 6. Outer cuticle showing crystals of various forms. V. 34455. × 400.

Glossopteris hispida n. sp.

FIG. 7. Upper cuticle showing numerous small surface papillae. V.34451*b*. × 400.



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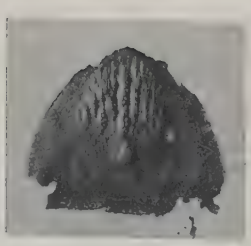

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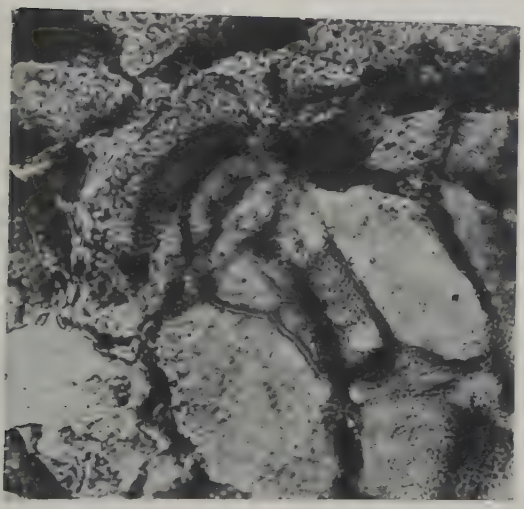

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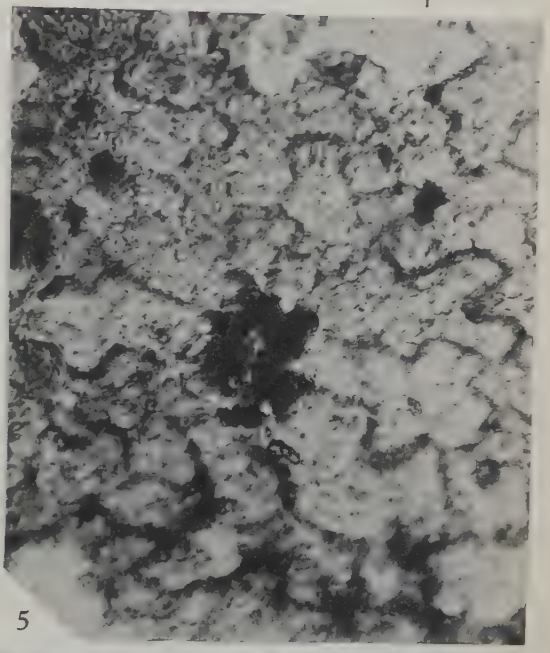

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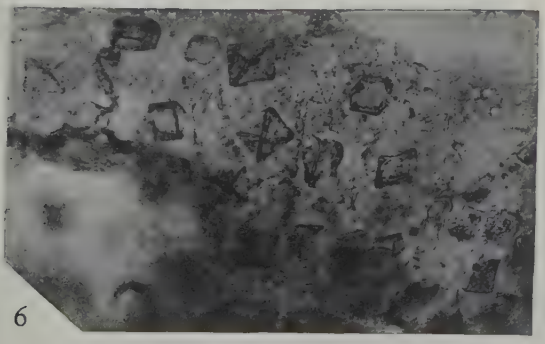

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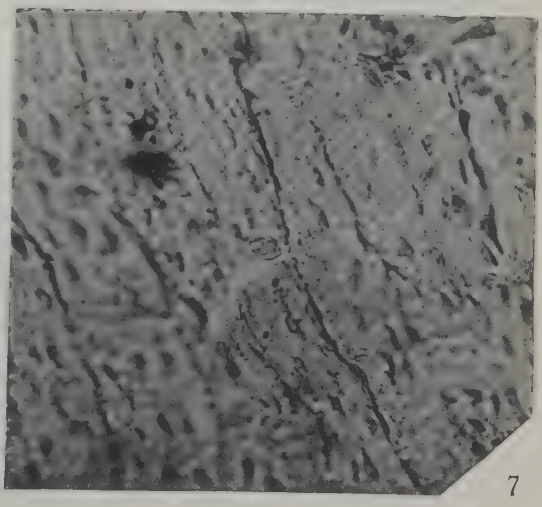


7

SPERMATITES, SCALE LEAVES, RHABDOTAENIA, GLOSSOPTERIS

PLATE 21

Sporangia

FIG. 1. Dehisced sporangium showing outer cuticle with elongated cells (near stalk) and inner cuticle with polygonal cells. Two-winged spores of varied size are seen inside the sporangium. V.34456. ×40.

FIG. 2. Sporangia borne terminally on branches of an axis. V. 34457. × 8.

FIG. 3. Dehisced sporangium showing gaps between the wall cells. V.34458. ×.40.

FIG. 4. Longitudinally flattened dehisced sporangium showing outer cuticle and a long stalk. V.34459. ×40.

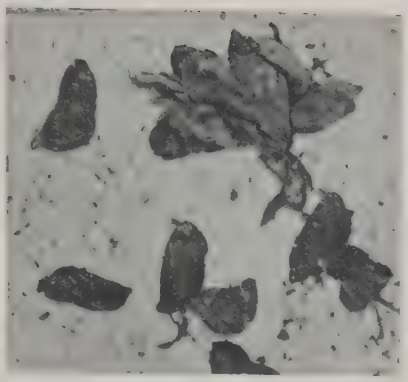
FIG. 5. Undehisced sporangium full of spores. V.34459. × 40.

FIG. 6. Two closed sporangia borne terminally on forks of a stalk. V.34460. × 40.

FIG. 7. A disc showing attached sporangia flattened in various planes. V.24233. × 6.

Figs. 1–6 from Mhukuru Coalfield, Tanganyika.
Fig. 7 from Newcastle, New South Wales.

1



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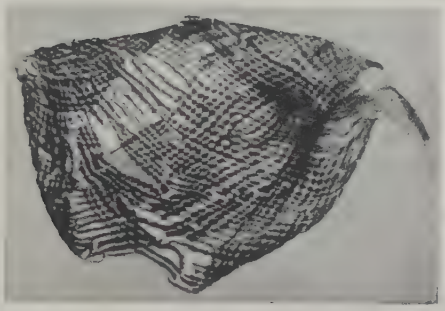

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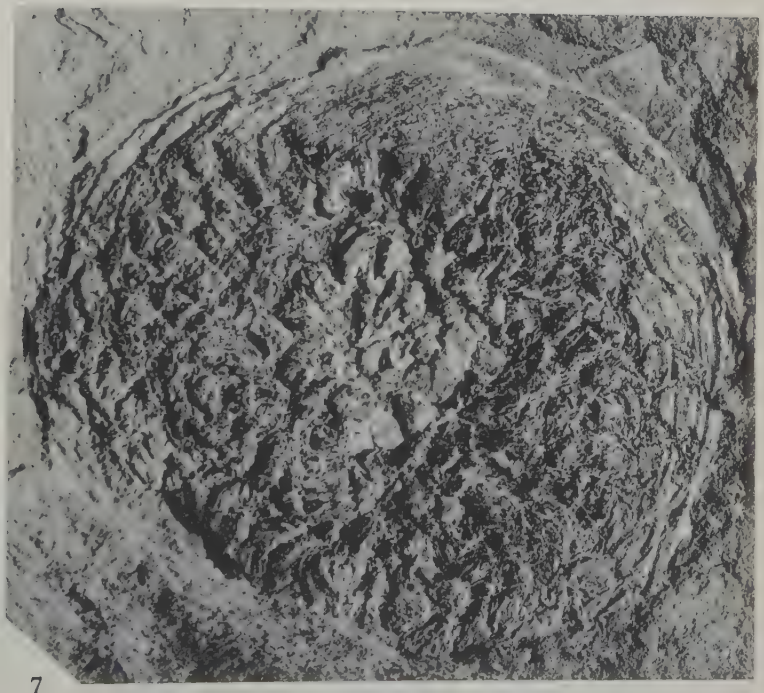

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SPORANGIA

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